



**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 1**

**EO M440.01 – IDENTIFY AEROSPACE MATERIALS**

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Total Time: 30 min

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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of the figures located at Attachments A and B.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for this lesson to introduce aerospace materials and to generate interest in the subject.

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**INTRODUCTION**

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**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to identify materials used in aerospace construction.

**IMPORTANCE**

It is important for cadets to learn about materials used in aerospace construction, as it will enhance their understanding of the materials used to build spacecraft and why they are chosen.

**Teaching Point 1****Discuss metals used in aerospace construction.**

Time: 15 min

Method: Interactive Lecture

**METALS USED IN AEROSPACE CONSTRUCTION**

During this TP, pass around samples of small pieces of components made from aluminum, magnesium, titanium, and stainless steel.

**Aluminum**

Pure aluminum lacks sufficient strength to be used for aerospace construction. However, its strength increases considerably when it is alloyed, mixed with other compatible metals. For example, when aluminum is mixed with copper or zinc, the resultant aluminum alloy is as strong as steel, with only one-third the weight. As well, the considerable corrosion resistance possessed by the aluminum carries over to the newly formed alloy. Aluminum is the most commonly used metal for spacecraft structure.

**Magnesium**

Magnesium is one of the lightest metals with sufficient strength and suitable working characteristics for use in aerospace structures. That is, in its pure form it lacks sufficient strength but, like aluminum, mixing it with other metals to create an alloy produces strength characteristics that make magnesium useful.

**Titanium**

Titanium and its alloys are lightweight metals with very high strength. Pure titanium weighs only half as much as stainless steel and is soft and ductile. Titanium alloys have excellent corrosion resistance, particularly to salt water.

**Stainless Steel**

Stainless steel is a classification of corrosion-resistant steel that contains large amounts of chromium and nickel. It is well suited to high-temperature applications such as firewalls and exhaust system components.

**MATERIAL TESTS**

The study of materials used in aerospace construction is vast and growing rapidly as scientists and engineers gain experience using materials, both new and old, in frontier applications and environments. All materials represent opportunity, but they must be correctly used. Space includes a variety of environments, each with different challenges, such as the Low Earth Orbit (LEO) environment encountered by the International Space Station (ISS) and space shuttle missions. Materials are selected for use in applications after careful study in laboratories, including laboratories in orbit such as the Long Duration Exposure Facility (LDEF).

LDEF was deployed in orbit on April 7, 1984 by the Shuttle Challenger. The nearly circular orbit was at an altitude of 275 nautical miles. LDEF remained in space for about 5.7 years and completed 32,422 Earth orbits. It experienced one-half of a solar cycle, as it was deployed during a solar minimum and retrieved at a solar maximum. LDEF was retrieved on January 11, 1990 by the Shuttle Columbia. By the time LDEF was retrieved, its orbit had decayed to 175 nautical miles and was a little more than one month away from re-entering the atmosphere.



The Long Duration Exposure Facility (LDEF) Archive System, maintained by NASA Langley Research Center, is designed to provide spacecraft designers and space environment researchers with a single point access to all available resources from LDEF. It is found at <http://setas-www.larc.nasa.gov/LDEF/index.html>

## ORBIT ENVIRONMENT

The characteristics of a spacecraft's orbit are determined by its mission. Some spacecraft travel between worlds and must be capable of functioning in a variety of conditions. Most spacecraft, however, are used in an application that restricts them to a narrow range of space environments. The relative impact of any of the space environments' effects on materials depends on the type of mission the spacecraft has to perform (eg, communications, defense, Earth observing) and, more important, the orbits in which the spacecraft is placed.



Show the cadets the slide of Figure A-1 located at Attachment A.

Figure A-1 shows the variations in the space environment as a function of orbit altitude. LEO extends up to 1000 km. Mid-Earth Orbit (MEO) is above 1000 km and extends up to 35 000 km. Geosynchronous orbit (GEO) is 35 000 km and higher.



Show the cadets the slide of Figures A-2 and A-3 located at Attachment A.

Major space environment hazards in LEO include atomic oxygen, ultraviolet radiation, frequent cycling between hot and cold temperatures, micrometeoroids, debris and contamination.



Atomic oxygen (AO) is an elemental form of oxygen that does not exist in the Earth's atmosphere. In space, however, it is common in the LEO area where satellites orbit the Earth. There, it reacts with other materials very easily and exposes satellites and spacecraft to damaging corrosion. Researchers at NASA's Glenn Research Center study these damaging effects in order to find materials and methods to extend the lifetime of communication satellites, the Space Shuttles and the ISS.



Show the cadets the slide of Figure A-4 located at Attachment A.

To prevent AO from damaging metal surfaces, protective coatings are applied to the metal's surface. AO flux and ultraviolet radiation interact in the degradation of silver and Teflon materials.



Cadets can explore Space Weather: Impact of the Orbital Environment on the MOST microsatellite mission at <http://www.astro.ubc.ca/MOST/posters/WS-Kristy-poster.jpg>

Orbital debris is another hazard for materials in LEO. This refers to man-made particles orbiting the Earth. Within about 2 000 km above Earth's surface there is an estimated 3 000 000 kg of man-made orbiting objects. These objects are in mostly high inclination orbits and sweep past one another at an average speed of 10 km / second. These particles are a result of standard launch and spacecraft operations as well as rocket and satellite breakups. Launch and spacecraft operations place both large particles (eg, greater than 1-cm diameter such as satellite shrouds, lens covers, and dropped tools) and small particles (eg, approximately 10-micron diameter solid rocket exhaust) in orbit.

Impacts can alter material states and expose underlying materials, allowing the space environments (eg, AO) to further increase the damage area and begin damaging previously unexposed areas. AO undercutting of polymer substrates under protective coatings is a phenomenon that can be a concern for space applications of multi-layer insulation.

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## CONFIRMATION OF TEACHING POINT 1

### QUESTIONS:

- Q1. Why is pure aluminum unsuitable for use in many applications of aerospace construction?
- Q2. What three characteristics make titanium useful for aerospace components?
- Q3. What two metals are mixed with steel to make stainless steel?

### ANTICIPATED ANSWERS:

- A1. Pure aluminum lacks sufficient strength for aerospace construction.
- A2. Titanium alloys have high strength, are lightweight and are resistant to corrosion.
- A3. Steel is mixed with chromium and nickel.

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## Teaching Point 2

**Discuss composite materials used in aerospace construction.**

Time: 10 min

Method: Interactive Lecture

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## COMPOSITE CONSTRUCTION



The term composite refers to a combination of two or more materials that differ in composition or form. Composite is sometimes used to mean any synthetic building material.

Composite structures differ from metallic structures in important ways: excellent elastic properties, high strength combined with light weight and the ability to be customized in strength and stiffness. The fundamental nature of many composites comes from the characteristics of a strong fibre cloth imbedded in a resin.



Pass around clearly marked samples of fibreglass cloth, aramid cloth and carbon fibre cloth.

### Fibreglass

Fibreglass is made from strands of silica glass that are spun together and woven into cloth. Fibreglass weighs more and has less strength than most other composite fibres. However, improved matrix materials now allow fibreglass to be used in advanced composite aerospace applications.

There are different types of glass used in fibreglass: E-glass, which has a high resistance to electric current and S-glass, which has a higher tensile strength, meaning that the fabric made from it resists tearing.

### Aramid

Aramid is a polymer. A polymer is composed of one or more large molecules that are formed from repeated units of smaller molecules.



Ask the cadets to name all the applications they are aware of for Kevlar®.

The best-known aramid material is Kevlar®, which has a tensile strength approximately four times greater than the best aluminum alloy. This cloth material is used in many applications where great strength is needed: canoes, body armour and helicopter rotors. Aramid is ideal for aerospace parts that are subject to high stress and vibration. The aramid's flexibility allows it to twist and bend in flight, absorbing much of the stress. In contrast, a metal part would develop fatigue and stress cracks sooner under the same conditions.

### Carbon / Graphite

The term carbon is often used interchangeably with the term graphite; however, they are not quite the same material. Carbon fibres are formed at 1315 degrees Celsius (2400 degrees Fahrenheit), but graphite fibres are produced only above 1900 degrees Celsius (3450 degrees Fahrenheit). As well, their actual carbon content differs—but both carbon and graphite materials have high compressive strength and stiffness.

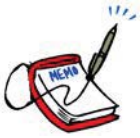
Carbon molecules will form long strings that are extremely tough (this is what makes diamonds so strong). These minute hair-like strands of carbon (a very common and inexpensive element) are, per unit of weight, many times stronger than steel. Individual carbon fibres are flexible, rather than stiff, and bend easily despite having high tensile strength. To stiffen the fibres, cross-directional layers are immersed in a matrix material such as epoxy plastic. A matrix is any material that sticks them together.



The term epoxy refers to a substance derived from an epoxide. An epoxide is a carbon compound containing an oxygen atom bonded in a triangular arrangement to two carbon atoms. So, an epoxy matrix is itself carbon-based, as are the fibres that it binds.

### Ceramic

Ceramic fibre is a form of glass fibre designed for use in high temperature applications. It can withstand temperatures approaching 1650 degrees Celsius (3000 degrees Fahrenheit), making it effective for use around engines and exhaust systems.



Show the cadets the slide of Figure B-1 located at Attachment B.

Ceramic's disadvantages include both weight and expense, but sometimes no other known material will do the job. One of the most famous applications of ceramic is the Thermal Protection System (TPS) used on the space shuttle. The properties of aluminum demand that the maximum temperature of the shuttle's structure be kept below 175 degrees Celsius (350 degrees Fahrenheit) during operations. Heating during re-entry (in other words, heating caused by friction with the air) creates surface temperatures high above this level, and in many places will push the temperature well above the melting point of aluminum (660 degrees Celsius or 1220 degrees Fahrenheit).



Underneath its protective layer of tiles and other materials, the space shuttle has an ordinary aluminum construction, similar to many large aircraft.



Show the cadets the slide of Figure B-2 located at Attachment B.

A space shuttle's TPS is very complex and it contains highly sophisticated materials. Thousands of tiles of various sizes and shapes cover a large percentage of the space shuttle's exterior surface. There are two main types of silica ceramic tiles used on the space shuttle:

- **Low-Temperature Reusable Surface Insulation (LRSI).** LRSI tiles cover relatively low-temperature areas of one of the shuttles, the Columbia, where the maximum surface temperature runs between 370 and 650 degrees Celsius (700 and 1200 degrees Fahrenheit), primarily on the upper surface of fuselage around the cockpit. These tiles have a white ceramic coating that reflects solar radiation while in space, keeping the Columbia cool.



Show the cadets the slide of Figure B-3 located at Attachment B.

- **High-Temperature Reusable Surface Insulation (HRSI).** HRSI tiles cover areas where the maximum surface temperature runs between 650 and 1260 degrees Celsius (1200 and 2300 degrees Fahrenheit). They have a black ceramic coating, which helps them radiate heat during re-entry.

Both LRSI and HRSI tiles are manufactured from the same material and their primary difference is the coating.

A different and even more sophisticated material, Reinforced Carbon-Carbon (RCC), is used for the nose cone and leading edges of the space shuttle. It is a composite material consisting of carbon fibre reinforcement in a matrix of graphite, often with a silicon carbide coating to prevent oxidation.

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**CONFIRMATION OF TEACHING POINT 2****QUESTIONS:**

- Q1. What type of glass is used in fibreglass strands?
- Q2. What is the best known aramid material?
- Q3. What method is used to stiffen carbon fibre materials?

**ANTICIPATED ANSWERS:**

- A1. Silica glass.
- A2. Kevlar<sup>®</sup>.
- A3. Immersing cross-directional layers of carbon fibres in a matrix compound such as epoxy plastic.

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**END OF LESSON CONFIRMATION****QUESTIONS:**

- Q1. What are the altitudes of LEO, MEO and GEO orbits?
- Q2. What is the major gas found in LEO?
- Q3. What is the most commonly used metal for spacecraft structure?

**ANTICIPATED ANSWERS:**

- A1. LEO extends up to 1 000 km, MEO is above 1 000 km and extends up to 35 000 km, and GEO is 35 000 km and higher.
- A2. The major gas in LEO is AO.
- A3. Aluminum is the most commonly used metal for spacecraft structure.

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**CONCLUSION**

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**HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

The study of materials used in aerospace construction is a rapidly growing field that holds immense opportunity for development. Space travel demands accurate and creative materials applications.

**INSTRUCTOR NOTES / REMARKS**

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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**REFERENCES**

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C3-136 ISBN 0-88487-207-6 Sanderson Training Systems (2001). *A&P technician airframe textbook*. Englewood, CO: Jeppesen Sanderson Inc.

C3-294 Silverman, E. M. (1995). *Space environmental effects on spacecraft: LEO materials selection guide*. Hampton, VA: NASA Langley Research Center. Retrieved November 27, 2008, from <http://see.msfc.nasa.gov/mp/NASA-95-cr4661pt1.pdf>



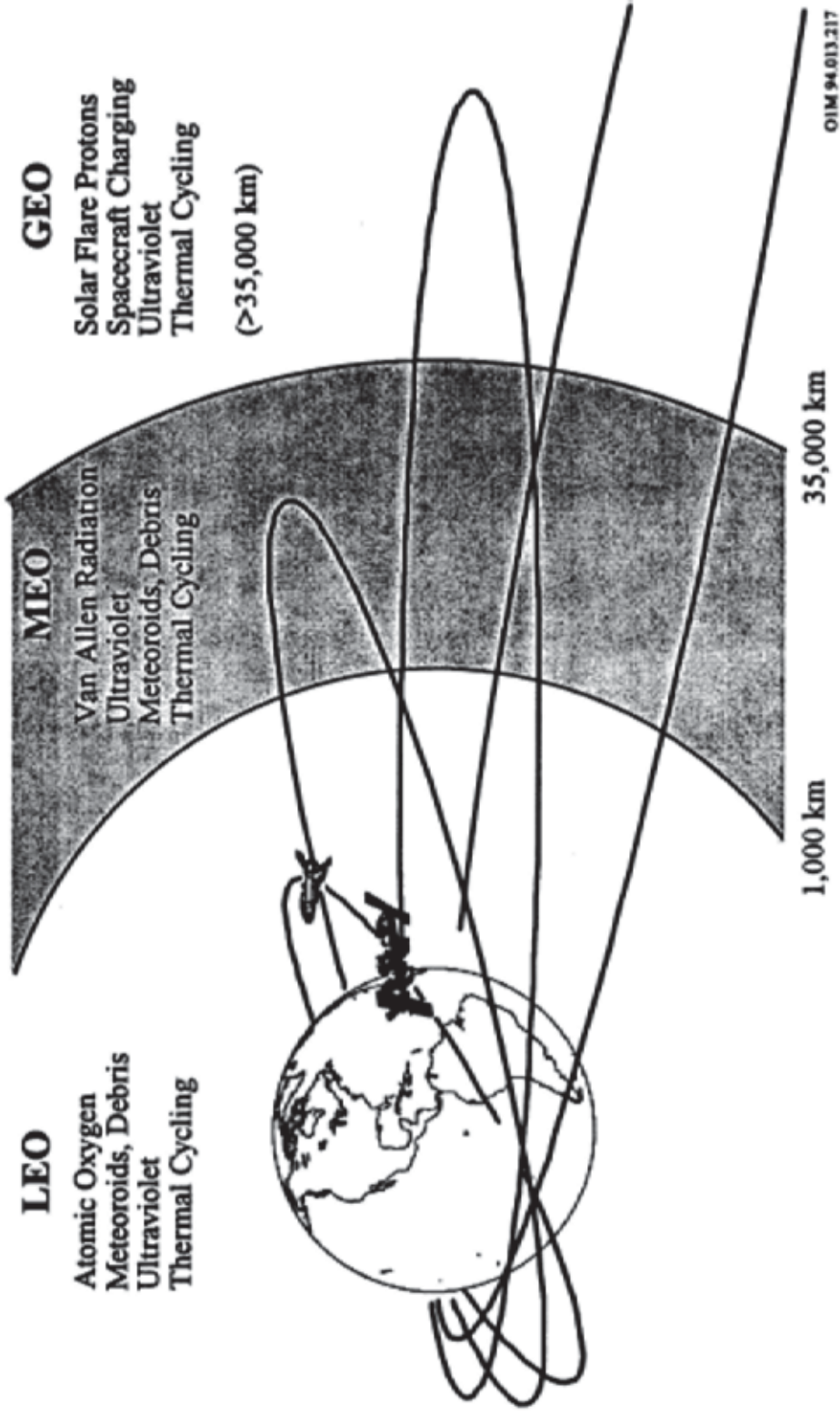


Figure A-1 Variation of Space Environments With Altitude

Note: From *Space Environmental Effects on Spacecraft: LEO Materials Selection Guide*, by E. M. Silverman, 1995, Hampton, VA: NASA Langley Research Center. Retrieved November 27, 2008, from <http://see.msfc.nasa.gov/mp/NASA-95-cr4661pt1.pdf>

<b>Impact</b>	<b>Significance</b>
10	Effects produced will negate the mission
9	Effects produced may negate the mission
8	Effects produced will shorten the mission
7	Effects produced may shorten the mission
6	Effects produced will reduce mission effectiveness
5	Effects produced may reduce mission effectiveness
4	Effects produced will require design changes
3	Effects produced may require design changes
2	Effects produced will cause upsets
1	Effects produced may cause upsets
0	Effects produced can be ignored

Figure A-2 Relative Ranking of the Space Environment Impact on Mission

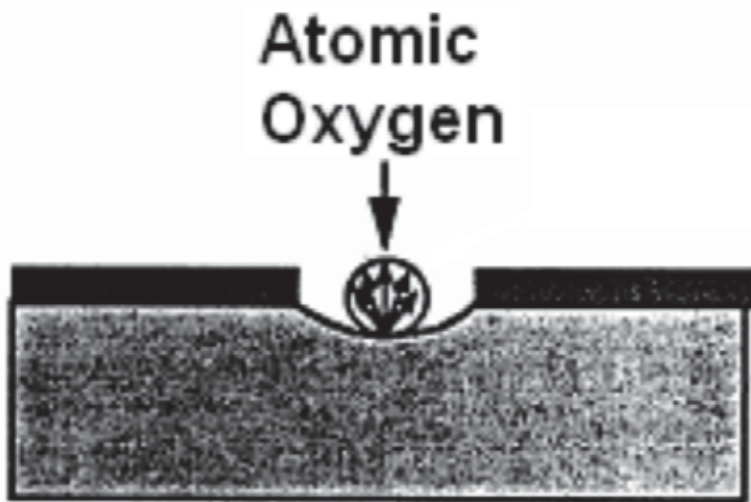
Note. From *Space Environmental Effects on Spacecraft: LEO Materials Selection Guide*, by E. M. Silverman, 1995, Hampton, VA: NASA Langley Research Center. Retrieved November 27, 2008, from <http://see.msfc.nasa.gov/mp/NASA-95-cr4661pt1.pdf>

Spacecraft Environment	LEO <sup>(1)</sup> Low Incl.	LEO High Incl.	MEO <sup>(2)</sup>	GEO <sup>(3)</sup>	Int'l Space Station 500 km 51.6° incl	GPS 20,000km 55° incl
Direct Sunlight	4 <sup>(4)</sup>	4	4	4	4	4
Gravity Field	3	3	3	0	3	0
Magnetic Field	3	3	3	0	3	0
Van Allen Belts	0-5	2-5	8-5	1	2-5	5
Solar flare Particles	0	4	3	5	4	3
Galactic Cosmic Rays	0	4	3	5	4	3
Debris Objects	7	7	3-0	3	7	0
Micrometeoroids	3	3	3	3	3	3
Ionosphere	3	3	1	0	3	0
Hot Plasma	0	3	0	5	0	3
Neutral Gases	9-7	9-7	3-0	0	9-7	0

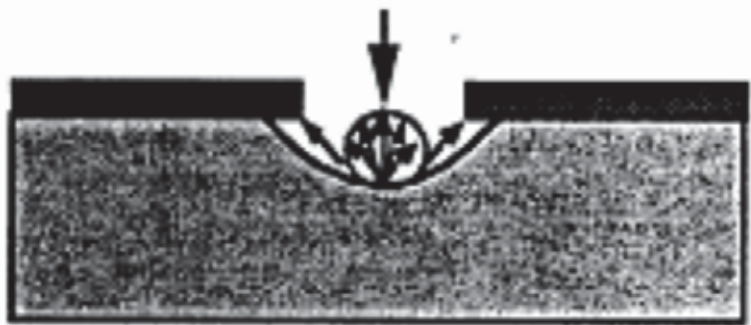
Figure A-3 Space Environmental Effects

Note: From *Space Environmental Effects on Spacecraft: LEO Materials Selection Guide*, by E. M. Silverman, 1995, Hampton, VA: NASA Langley Research Center. Retrieved November 27, 2008, from <http://see.msfc.nasa.gov/mp/NASA-95-cr4661pt1.pdf>

**Defect Site In  
Protective  
Coating**



**Initial  
Undercutting**



**Advanced  
Undercutting**



Figure A-4 Atomic Oxygen Undercutting

*Note.* From *Space Environmental Effects on Spacecraft: LEO Materials Selection Guide*, by E. M. Silverman, 1995, Hampton, VA: NASA Langley Research Center. Retrieved November 27, 2008, from <http://see.msfc.nasa.gov/mp/NASA-95-cr4661pt1.pdf>





Figure B-1 Testing Thermal Insulation in a Wind Tunnel

Note. From "US Centennial of Flight Commission", 2004, *Shuttle Thermal Protection System*. Retrieved November 25, 2007, from [http://www.centennialofflight.gov/essay/Evolution\\_of\\_Technology/TPS/Tech41.htm](http://www.centennialofflight.gov/essay/Evolution_of_Technology/TPS/Tech41.htm)

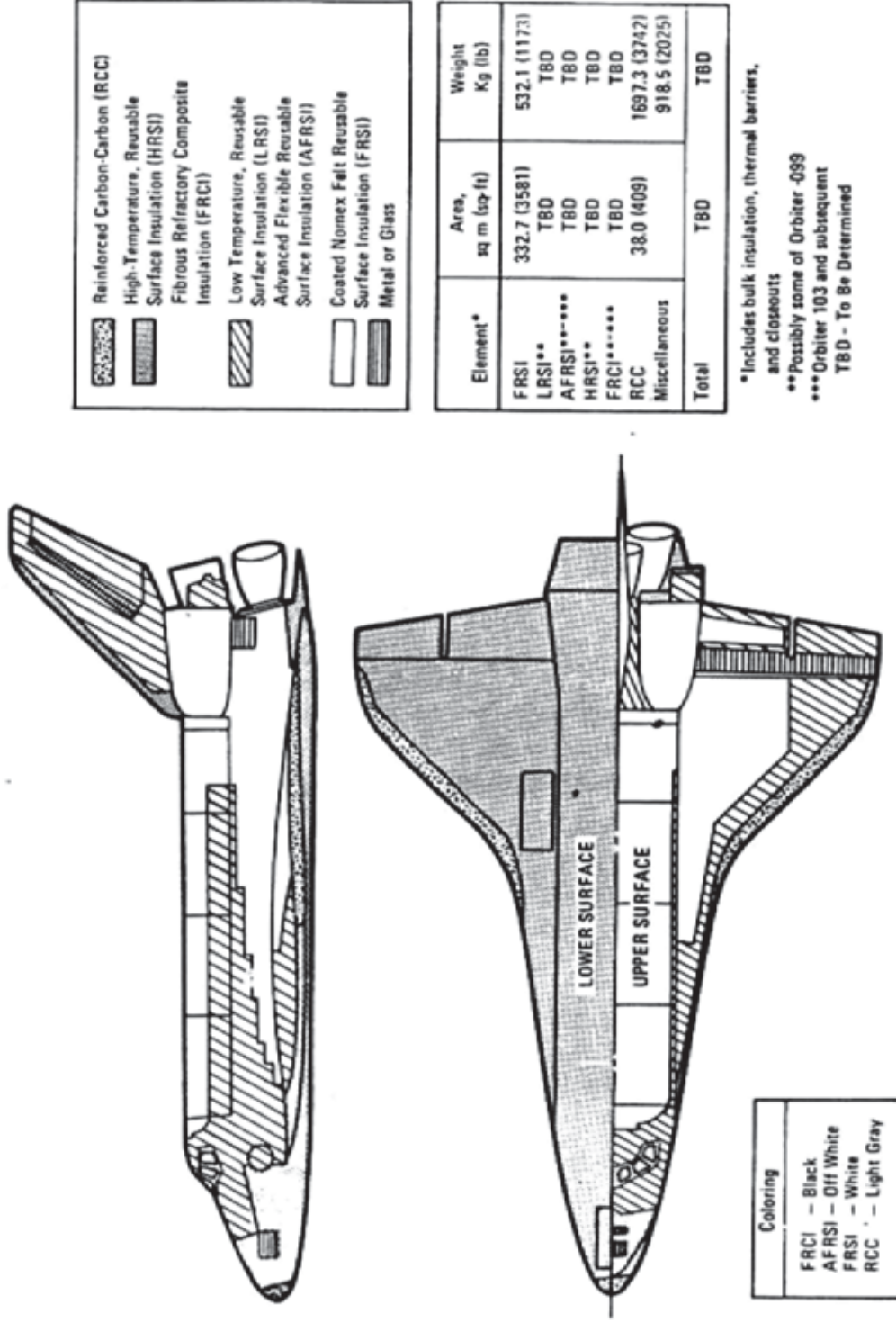


Figure B-2 Orbiter Thermal Protection System

Note. From "US Centennial of Flight Commission", 2004, *Shuttle Thermal Protection System*. Retrieved November 25, 2007, from [http://www.centennialofflight.gov/essay/Evolution\\_of\\_Technology/TPS/Tech4.1.htm](http://www.centennialofflight.gov/essay/Evolution_of_Technology/TPS/Tech4.1.htm)



Figure B-3 Repairing TPS on Columbia

*Note.* From "US Centennial of Flight Commission", 2004, *Shuttle Thermal Protection System*. Retrieved November 25, 2007, from [http://www.centennialofflight.gov/essay/Evolution\\_of\\_Technology/TPS/Tech41.htm](http://www.centennialofflight.gov/essay/Evolution_of_Technology/TPS/Tech41.htm)

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**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 2**

**EO M440.02 – DESCRIBE CANADIAN SATELLITES**

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Total Time: 30 min

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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Make slides of Attachments A–C.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for this lesson to orient the cadets to Canadian satellites and to generate interest in the subject.

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**INTRODUCTION**

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**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to describe selected Canadian satellites.

**IMPORTANCE**

It is important for cadets to be familiar with Canadian satellites so they can appreciate the Canadian space program, which is an important element of air cadet training.

**Teaching Point 1****Identify aspects of the Alouette program.**

Time: 5 min

Method: Interactive Lecture

**HISTORY**

Launched on September 29, 1962, the Alouette-I scientific satellite marked Canada's entry into the space age and was seen by many as initiating the most progressive space program of that era.



Show the cadets Figures A-1 and A-2 located at Attachment A.

With the Alouette launch, Canada became the first nation after the Soviet and American superpowers, to design and build its own artificial Earth satellite.

**PURPOSE**

The development of Alouette-I came as a result of an American invitation, through the newly formed National Aeronautics and Space Administration (NASA) in 1958, for international collaboration in its budding satellite program. Within months, scientists at Canada's Defence and Research Telecommunications Establishment (DRTE) submitted a proposal to NASA for a Canadian satellite that could monitor the top of the ionosphere, an upper layer of the earth's atmosphere that is ionized by solar wind.



The solar wind is so hot it becomes fully ionized plasma, which means that the atoms have become separated from their electrons. This streaming plasma flows past Earth, affects the Earth's magnetic field and magnetosphere, and creates the ionosphere by removing electrons from atoms of gas in the atmosphere. The Earth's atmosphere receives a lot of energy from the sun in the form of radiation—about 1 370 watts per square metre. That is enough energy to power six desktop computers, coming from an area that would barely hold one computer.

Ground-based techniques used to study the ionosphere are similar to radar. Radio pulses are transmitted from the ground and reflected back by the ionized layer of atmosphere. The elapsed time is used to calculate the height of the layers. The equipment used to make these measurements is an ionosonde. The Canadian proposal was to integrate an ionosonde into a satellite.

The objectives were twofold, both primary and scientific:

1. Primary objectives were:
  - a. to bring Canada into the space age by developing a space capability;
  - b. to contribute to space engineering and technology; and
  - c. to improve the capability of high frequency (HF) radio communications by studying the ionosphere from above.

2. Scientific objectives were:
  - a. to measure the electron density distribution in the ionosphere at altitudes between 300 and 1 000 km;
  - b. to study, for a one-year period, the variations of electron density distribution with regard to time of day and latitude under varying magnetic and auroral conditions, with particular emphasis on high latitude effects; and
  - c. to determine electron densities in the vicinity of the satellite by means of galactic noise measurement and to make observations of related physical phenomena, such as the flux of energetic particles.

### **ACCOMPLISHMENTS**

Alouette-I was a tremendous success. The conservative research approach adopted by the DRTE team paid off as the satellite eventually stretched its one-year design life into an unprecedented 10-year mission, producing more than one million images of the ionosphere.

Following the success of Alouette-I, Canada and the United States signed an agreement to launch further satellites under a new program called International Satellites for Ionospheric Studies (ISIS). Under the ISIS program, the Alouette backup model, Alouette-II, was refurbished and flown in 1965 and two new satellites, named ISIS I and ISIS II, were successfully launched in 1969 and 1970 respectively.

### **CONFIRMATION OF TEACHING POINT 1**

#### **QUESTIONS:**

- Q1. What was the year of Alouette's first launch?
- Q2. What was Alouette designed to do?
- Q3. What program followed the success of Alouette?

#### **ANTICIPATED ANSWERS:**

- A1. 1962.
- A2. To monitor the ionosphere from above.
- A3. The ISIS program.

### **Teaching Point 2**

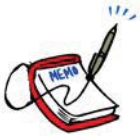
### **Identify aspects of the Microvariability and Oscillation of Stars (MOST) mission.**

Time: 10 min

Method: Interactive Lecture

### **HISTORY**

MOST is Canada's space telescope in orbit. It is sometimes referred to as the "Hubble Space Telescope" due to its physical size, despite its effectiveness and accomplishments.



Show the cadets Figures B-1 and B-2 located at Attachment B.

The four partners who designed and created MOST are:

- Canadian Space Agency (CSA),
- University of British Columbia (UBC) (Physics and Astronomy),
- University of Toronto Institute for Aerospace Studies (UTIAS), and
- Dynacon Enterprises Limited (main contractor, mission operations).

The MOST science team includes representatives from various organizations, which include:

- University of British Columbia (UBC),
- St. Mary's University,
- L'Université de Montréal,
- University of Toronto David Dunlap Observatory (DDO),
- Harvard-Smithsonian Center, and
- University of Vienna.

MOST was carried aloft aboard a Russian three-stage rocket on June 30, 2003, from a launch site in northern Russia (Plesetsk). MOST was injected into a low-Earth polar orbit at approximately 820 km altitude with an orbital period of approximately 100 minutes in a sun-synchronous mode remaining over the Earth's terminator (the line between day and night).



Sun-synchronous means that, although MOST orbits Earth, it also maintains its orientation to the sun.



Show the cadets Figures B-3 to B-5 located at Attachment B. For orbit information, cadets can visit <http://www.astro.ubc.ca/MOST/galleries.html#movies>

From that vantage point, MOST will have a Continuous Viewing Zone (CVZ) spanning declinations from about -19 to +36 degrees, in which a selected target star will remain observable for up to 60 days without interruption.



UBC has a collection of MOST training eClips and explanations located at their MOST website at <http://www.astro.ubc.ca/MOST/galleries.html#movies>

## PURPOSE

The stated purposes of the MOST space telescope are the detection and characterization of:

- acoustic oscillations in sun-like stars, including very old stars (metal-poor subdwarfs) and magnetic stars (roAp), to probe seismically their structures and ages;
- reflected light from giant exoplanets closely orbiting sun-like stars, to reveal their sizes and atmospheric compositions; and
- turbulent variations in massive evolved (Wolf-Rayet) stars to understand how they add gas to the interstellar medium.

MOST, therefore, is an attempt to answer important question about stars, such as:

- Can we understand our sun in the context of other stars?
- By putting a birthdate on the oldest stars in the solar neighbourhood, can we set a limit on the age of the universe?
- How do strong magnetic fields affect the physics of other stars and our own sun?
- What are mysterious planets around other stars really like?
- How did the atoms that make up our planet and our bodies escape from stars in the first place?

## ACCOMPLISHMENTS

Although the MOST space telescope is often referred to as the Hubble telescope because of its size next to the Hubble Space Telescope (HST), the accomplishments of MOST are anything but humble. MOST turned out to be a precocious child. The team of scientists and engineers—located from coast to coast across Canada and in Harvard and Vienna—has extended the capabilities of this "little telescope that could" to explore exoplanets (alien worlds around other stars). MOST has measured the properties of several of these planets, which are invisible even to the largest telescopes. Among the findings of MOST is a planet whose atmosphere is either so clear or so hazy that it reflects only four percent of the light it receives from its parent sun.



For information about MOST observations, visit the MOST Science website at <http://www.astro.ubc.ca/MOST/science.html>

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## CONFIRMATION OF TEACHING POINT 2

### QUESTIONS:

- Q1. What year was that the MOST telescope carried aloft?
- Q2. What sort of orbit does MOST have?
- Q3. What viewing opportunity does MOST's orbit provide?

**ANTICIPATED ANSWERS:**

- A1. 2003.
- A2. A low-Earth polar orbit.
- A3. A CVZ spanning declinations from about -19 to +36 degrees, in which a selected target star will remain observable for up to 60 days without interruption.

**Teaching Point 3****Identify aspects of the RADARSAT program.**

Time: 10 min

Method: Interactive Lecture

**HISTORY**

The RADARSAT program was born out of the need for effective monitoring of Canada's waters. Canada is a world leader in the operational use of space radar for sea ice monitoring. Earth-observation satellites have an advantage over aerial surveillance missions. Satellites operate day and night in all weather conditions and provide timely coverage of vast areas.



Show the cadets Figure C-1 located at Attachment C.

RADARSAT is Canada's first series of remote-sensing satellites. RADARSAT-1 was launched in 1995 and RADARSAT-2 in 2007. These satellites focus on the use of radar sensors to provide unique information about the Earth's surface through most weather conditions and darkness. A technique known as synthetic-aperture radar (SAR) is used by RADARSAT satellites to increase the resolution of images by taking advantage of the fact that the satellite's small aperture is constantly moving. The many echo waveforms received at the different antenna positions are then post-processed by a computer in order to resolve the target with high definition. Post-processing by a computer is also the technique used by Global Positioning System (GPS) receivers to eliminate location ambiguities.

**PURPOSE****Marine Surveillance**

Worldwide offshore resource-based operations such as fishing, oil and gas exploration and production have intensified over the past few decades. Government and industry require powerful solutions for assessing the resources and risks associated with the ocean environment. To monitor the world's oceans, Canada has provided radar data for operational applications such as ship detection, oil spill monitoring, and wind and surface-wave field estimation.

RADARSAT-2 improves ship detection with its ultra-fine beam mode, which can resolve objects down to 3 m on a side, and offers the potential for ship classification.

**Disaster Management**

Radar satellites are key resources in a variety of disaster management scenarios. The data has been used effectively in disaster responses such as earthquakes, tsunamis, floods, landslides, forest fires, and other natural or technological disasters such as a large oil spill in Japan. On January 2, 1997, the Nakhodka, a Russian oil tanker, broke apart during a storm 130 km (80 miles) off the coast of Japan's Shimane Prefecture.



Show the cadets Figure C-2 located at Attachment C. The inset view in Figure C-2 shows the location of the Wakasa Bay nuclear reactors.

At one point the spill threatened one of the most concentrated areas of nuclear reactors in the world. The oil slicks came close to the 15 reactors in Japan's Wakasa Bay but the cleanup effort was able to keep the oil from seeping into the reactor's intake pipes, which serve to cool the reactors with seawater. Officials stated that in the worst case, if the oil had seeped into the pipes, plant operators would simply have been forced to suspend power. RADARSAT images served to define the extent and shape of the oil spill during this disaster.



The ability to deliver data in near-real time is essential for relief operations to map and monitor damage and for assessing impact.

RADARSAT-2 reduces planning lead times for data acquisition and, because it can look both right and left, provides more revisits and up-to-date data than its predecessor.

There are unlimited uses for RADARSAT image data. An example is the use of RADARSAT images by Research Institute for Advanced Mechanics (RIAM) of the Kyushu University Dynamics Simulation Research Center to develop a computer model of the Nakhodka oil spill.



Show the cadets Figure C-3 located at Attachment C.

RADARSAT images, such as the ones seen in Figure C-3, were used in creating computer programs that simulate the spreading of spilled oil.



Show the cadets Figure C-4 located at Attachment C.

Dated images of the computer program output are shown in Figure C-4. Computer analysis is now available to predict the effects of future oil spills and assist with environmental cleanup.

## Hydrology

Water is one of Earth's most precious and widely used resources. RADARSAT-2 enhances soil moisture measurement, and snow pack monitoring and analysis, while improving the potential for SAR in wetland mapping and discrimination. This will benefit mapping applications involving coastlines, tidal and near-shore terrestrial areas, and near-shore bathymetry (depth measurements).

## Mapping

Mapping covers a broad range of activities, including the creation of Digital Elevation Models (DEMs), the detection and mapping of centimetre-scale movements at the Earth's surface (InSAR), and the extraction and identification of features to support environment management and security.

RADARSAT-2's advanced technology provides improved capabilities for mapping. Highly accurate positional information and control over the RADARSAT-2 orbit ensures absolute quality for end products, such as DEMs and InSAR.

### **Geology**

Satellite radar data is very useful in geological exploration and mapping activities for petroleum and mineral resources. Canadian radar data is used for both onshore and offshore exploration and mapping and to monitor and detect oil seeps, which reduces the risk and cost of drilling. The Southern African Institute of Mining and Metallurgy reports the use of remote sensing by diamond mining companies in South Africa, listing RADARSAT images as among the most useful.

### **Agriculture**

Abundant harvests and crop yields partly depend on soil dynamics that fluctuate throughout the growing season. Satellite imagery is an efficient method for mapping crop characteristics over large spatial areas and tracking temporal changes in soil and crop conditions.

Built into RADARSAT-2 are several powerful features that respond directly to the needs of the agricultural sector. Valuable crop information can be extracted from one RADARSAT-2 image and there is no need for image data acquisition over several dates. RADARSAT provides important information about climate change.

### **Forestry**

With more than 30 percent of the Earth's total land area covered in forests, it is no small feat to assess and monitor forest resources. Satellite imagery is the most efficient method for coverage of forested areas.

Several applications in forestry have benefited from Canadian radar data, in particular clear-cut mapping. High-resolution data from RADARSAT-2 may improve forest-type mapping using textural analysis.

## **ACCOMPLISHMENTS**

The RADARSAT Program continues Canada's tradition of providing world leadership in advancing Earth-observation technologies and techniques. Natural Resources Canada—one of RADARSAT's main customers—observes that RADARSAT's unparalleled operational flexibility and reliable delivery provides high quality and cost-effective data to researchers and environmental professionals world-wide.

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## **CONFIRMATION OF TEACHING POINT 3**

### **QUESTIONS:**

- Q1. What kind of satellites are RADARSAT satellites?
- Q2. In what year was the first RADARSAT launch?
- Q3. What are three purposes of the RADARSAT program?

### **ANTICIPATED ANSWERS:**

- A1. Earth-observation satellites.
- A2. RADARSAT-1 was launched in 1995.
- A3. Any three chosen from: marine surveillance, disaster management, hydrology, mapping, geology, agriculture and / or forestry.



---

**END OF LESSON CONFIRMATION****QUESTIONS:**

- Q1. What job was Alouette designed to do?
- Q2. What does MOST's orbit provide?
- Q3. What are three purposes of the RADARSAT program?

**ANTICIPATED ANSWERS:**

- A1. To monitor the ionosphere from above.
- A2. A CVZ spanning declinations from about -19 to +36 degrees, in which a selected target star will remain observable for up to 60 days without interruption.
- A3. Any three chosen from: marine surveillance, disaster management, hydrology, mapping, geology, agriculture and / or forestry.

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**CONCLUSION**

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**HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

Canadian space missions affect many aspects of life, from telecommunications to environmental protection and pure science. Intended and unintended applications of Canada's space research continue to benefit other industries.

**INSTRUCTOR NOTES / REMARKS**

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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**REFERENCES**

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C3-253 Canadian Space Agency. (2008). *Alouette I and II*. Retrieved September 29, 2008, from <http://www.space.gc.ca/asc/eng/satellites/alouette.asp>

C3-254 University of British Columbia. (2008). *MOST: Canada's first space telescope*. Retrieved September 29, 2008, from <http://www.astro.ubc.ca/MOST/overview.html#glance>

C3-255 Natural Resources Canada. (2008). *Canada centre for remote sensing: RADARSAT*. Retrieved September 29, 2008, from [http://www.ccrs.nrcan.gc.ca/radar/spaceborne/radarsat1/index\\_e.php](http://www.ccrs.nrcan.gc.ca/radar/spaceborne/radarsat1/index_e.php)

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Figure A-1 Alouette-1

Note. From Canadian Space Agency, 2008, *Alouette I and II*. Retrieved October 27, 2008, from [http://www.space.gc.ca/asc/app/gallery/results2.asp?session=&image\\_id=alouette](http://www.space.gc.ca/asc/app/gallery/results2.asp?session=&image_id=alouette)

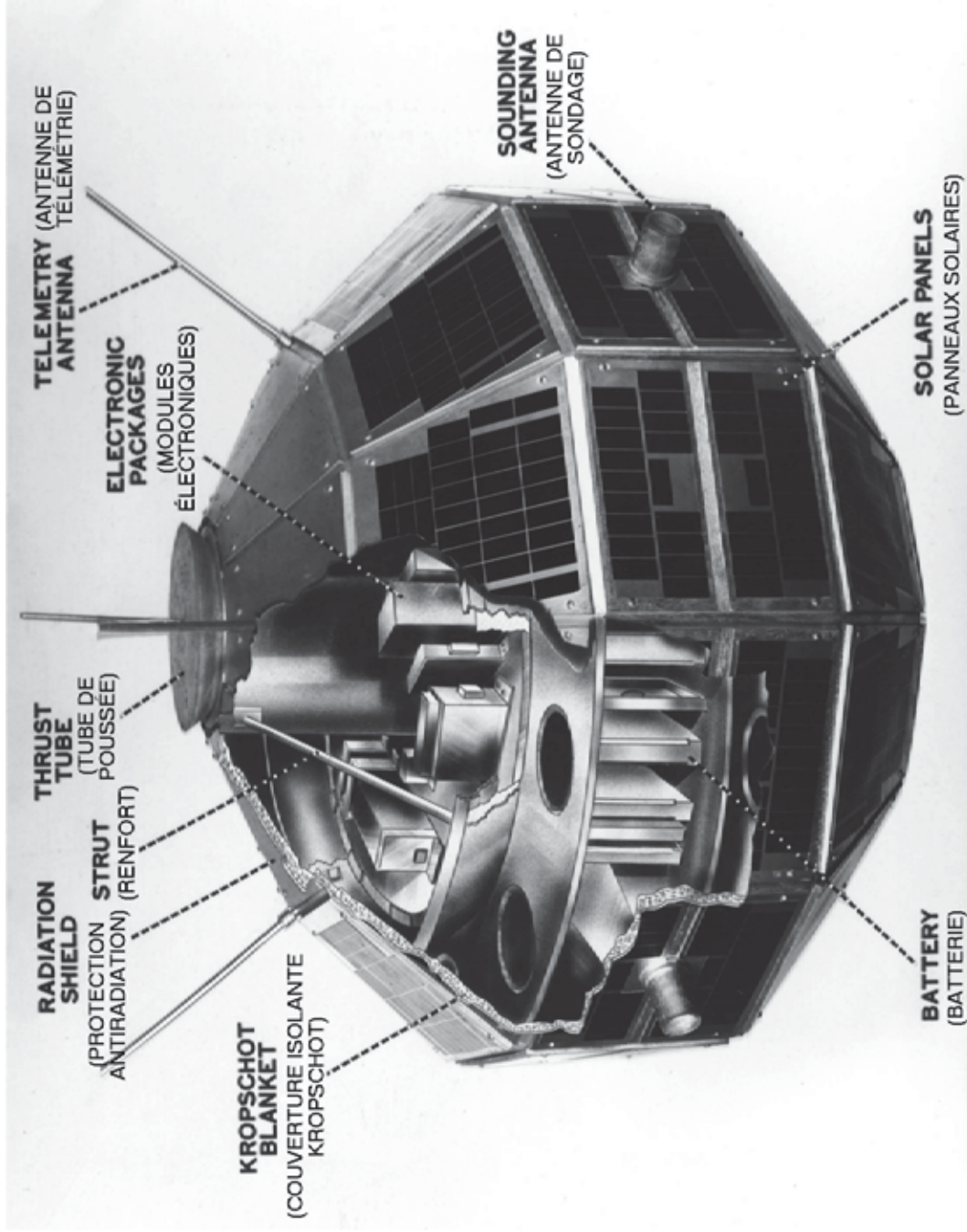


Figure A-2 Alouette-1 Revealed

Note. From Canadian Space Agency, 2008, *Alouette I and II*. Retrieved October 27, 2008, from [http://www.space.gc.ca/asc/app/gallery/results2.asp?session=&image\\_id=jhchapman-03](http://www.space.gc.ca/asc/app/gallery/results2.asp?session=&image_id=jhchapman-03)

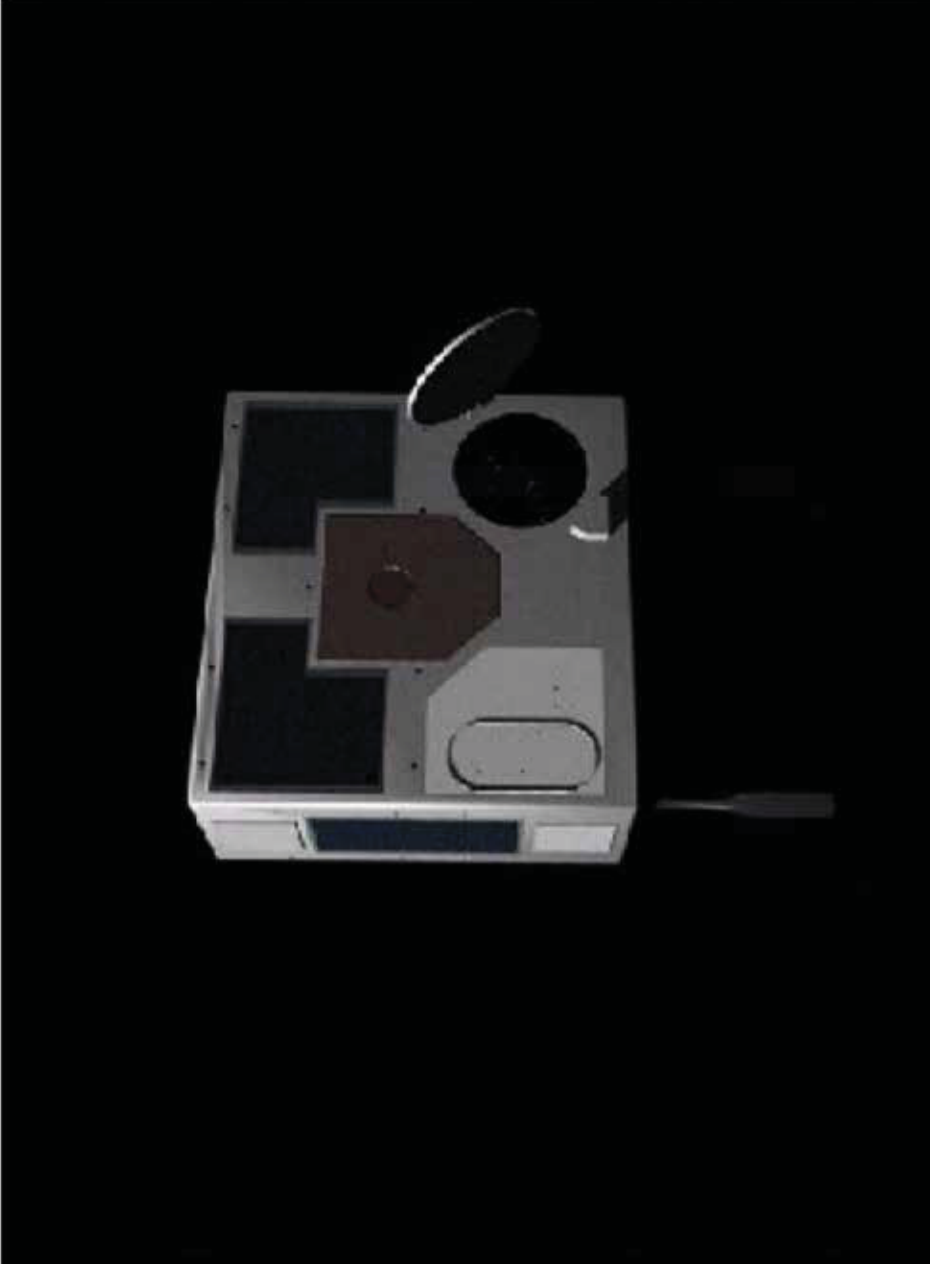


Figure B-1 MOST With Telescope Protective Door Open

Note. From "MOST: Canada's First Space Telescope", 2008, *Galleries*. Retrieved October 27, 2008, from <http://www.astro.ubc.ca/MOST/galleries.html#movies>



Figure B-2 The Hubble and the Humble to Scale

Note. From "MOST: Canada's First Space Telescope", 2008, *Galleries*. Retrieved October 27, 2008, from <http://www.astro.ubc.ca/MOST/galleries.html#movies>

**MOST Orbit**  
**827 km height**  
**98.7 deg inclination**

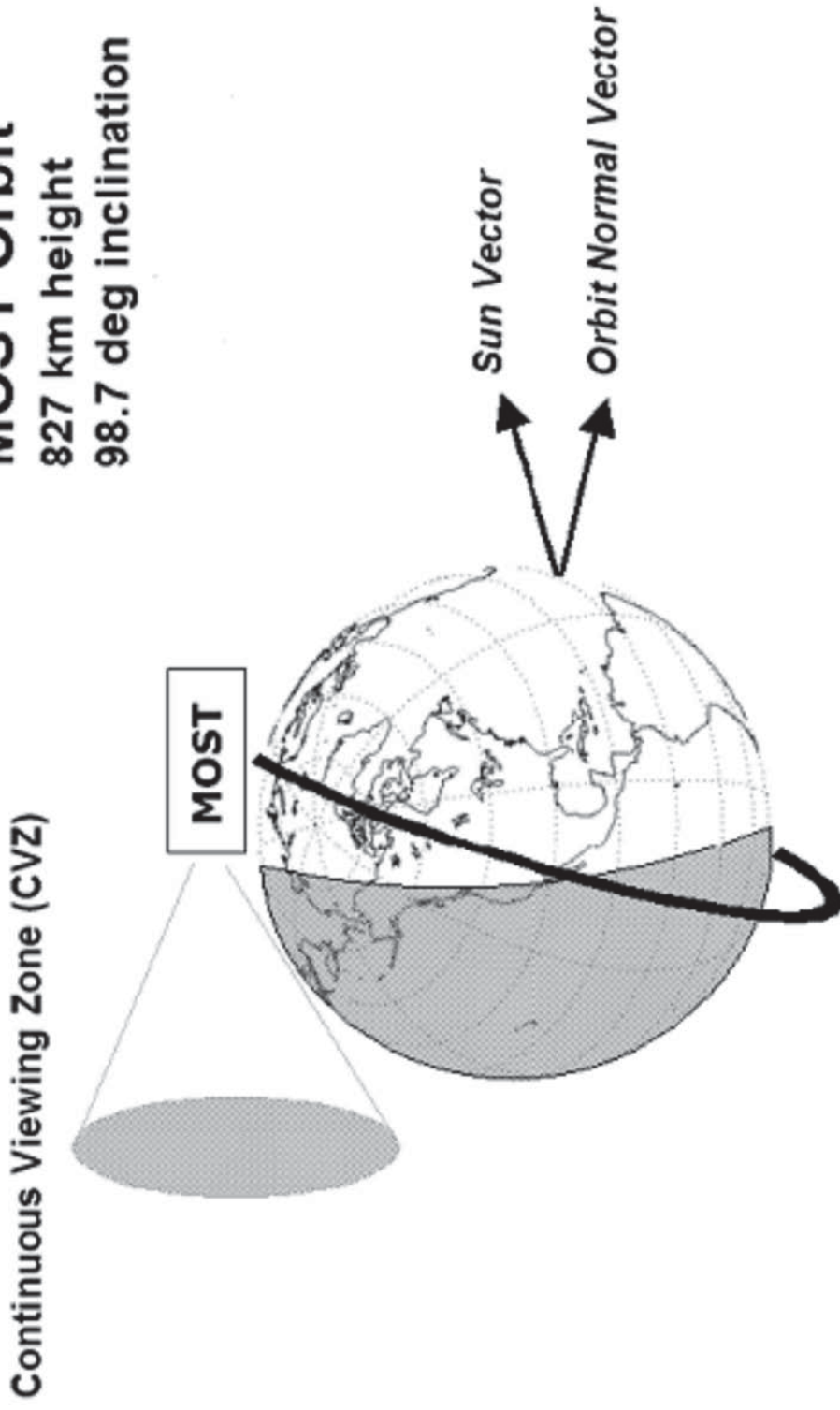


Figure B-3 MOST's Sun-Synchronous Polar Orbit

Note. From *The MOST Asteroisemology Mission: Ultraprecise Photometry from Space*, 2003, by G. Walker, J. Matthews, R. Kuschnig, & R. Johnson. Retrieved October, 20, 2008, from <http://www.astro.ubc.ca/MOST/papers/walker.pdf>



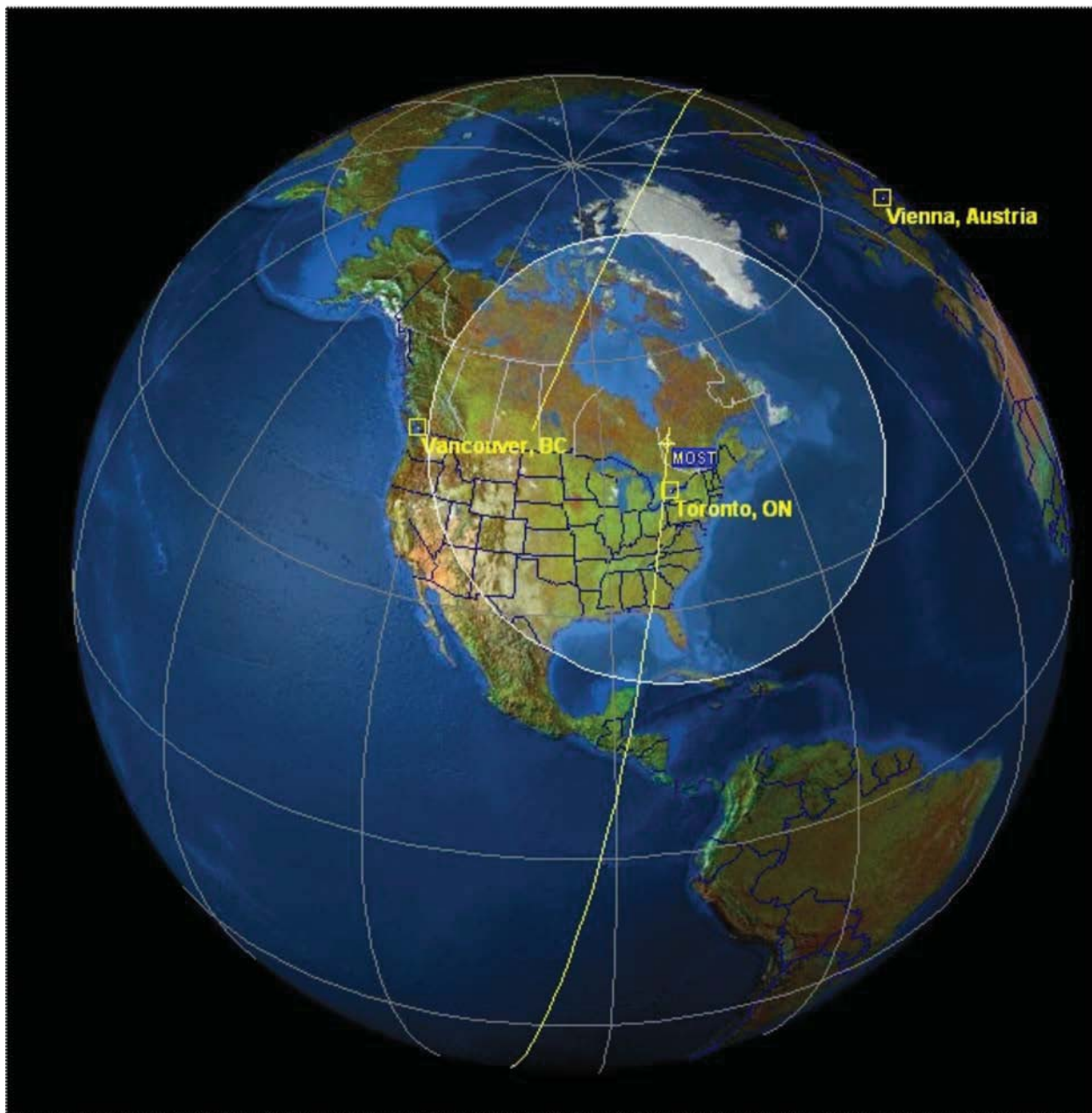


Figure B-4 MOST and Its Ground Stations

*Note.* From "MOST: Canada's First Space Telescope", 2008, *Galleries*.  
Retrieved October 27, 2008, from <http://www.astro.ubc.ca/MOST/galleries.html>





Figure B-5 MOST in Orbit

Note. From "MOST: Canada's First Space Telescope", 2008, Galleries. Retrieved October 27, 2008, from <http://www.astro.ubc.ca/MOST/galleries.html>

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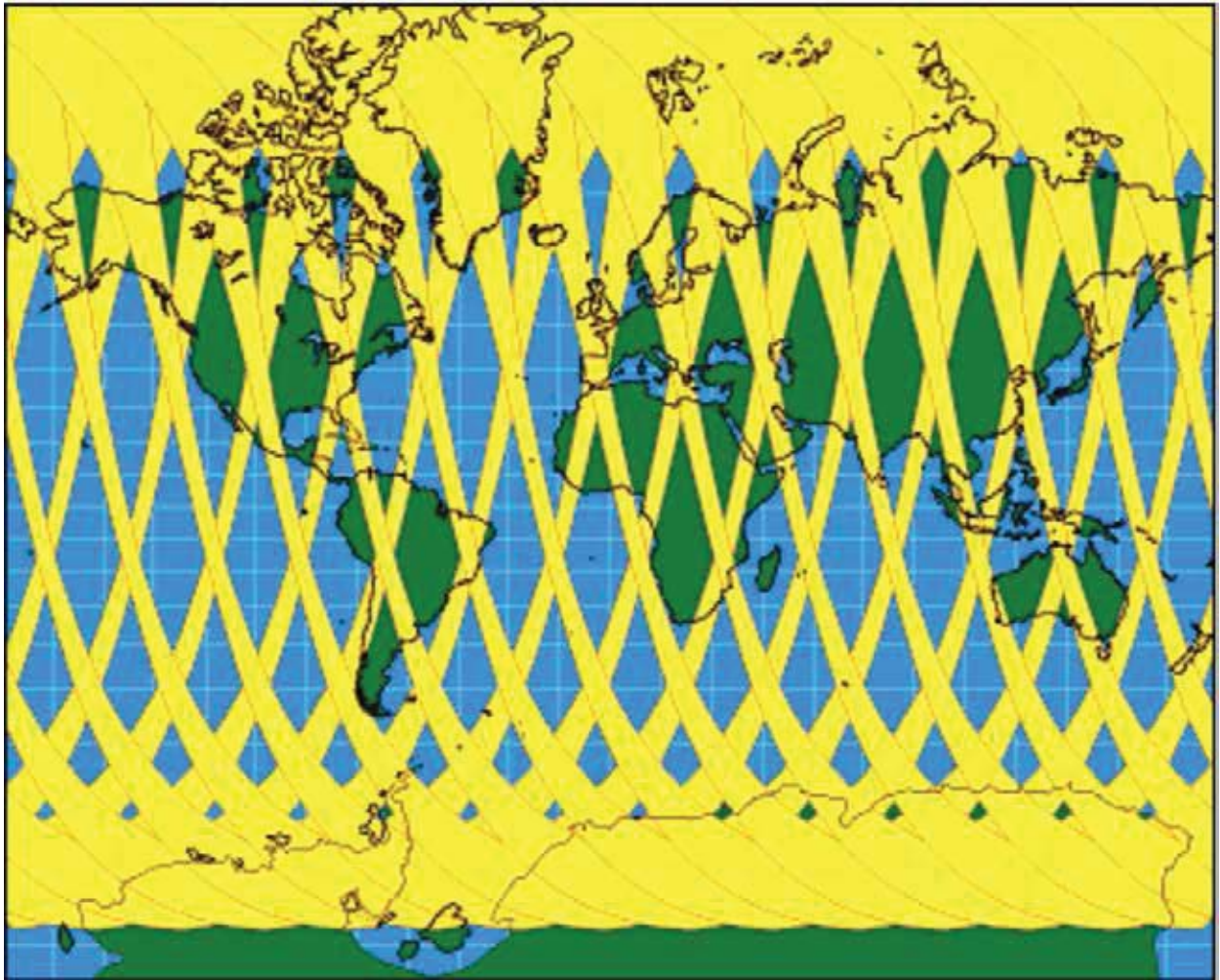


Figure C-1 RADARSAT Coverage

*Note.* From Natural Resources Canada, 2008, "Canada Centre for Remote Sensing", *RADARSAT-1 Overview*. Retrieved October 27, 2008, from [http://www.ccrs.nrcan.gc.ca/radar/spaceborne/radarsat1/specs/index\\_e.php](http://www.ccrs.nrcan.gc.ca/radar/spaceborne/radarsat1/specs/index_e.php)



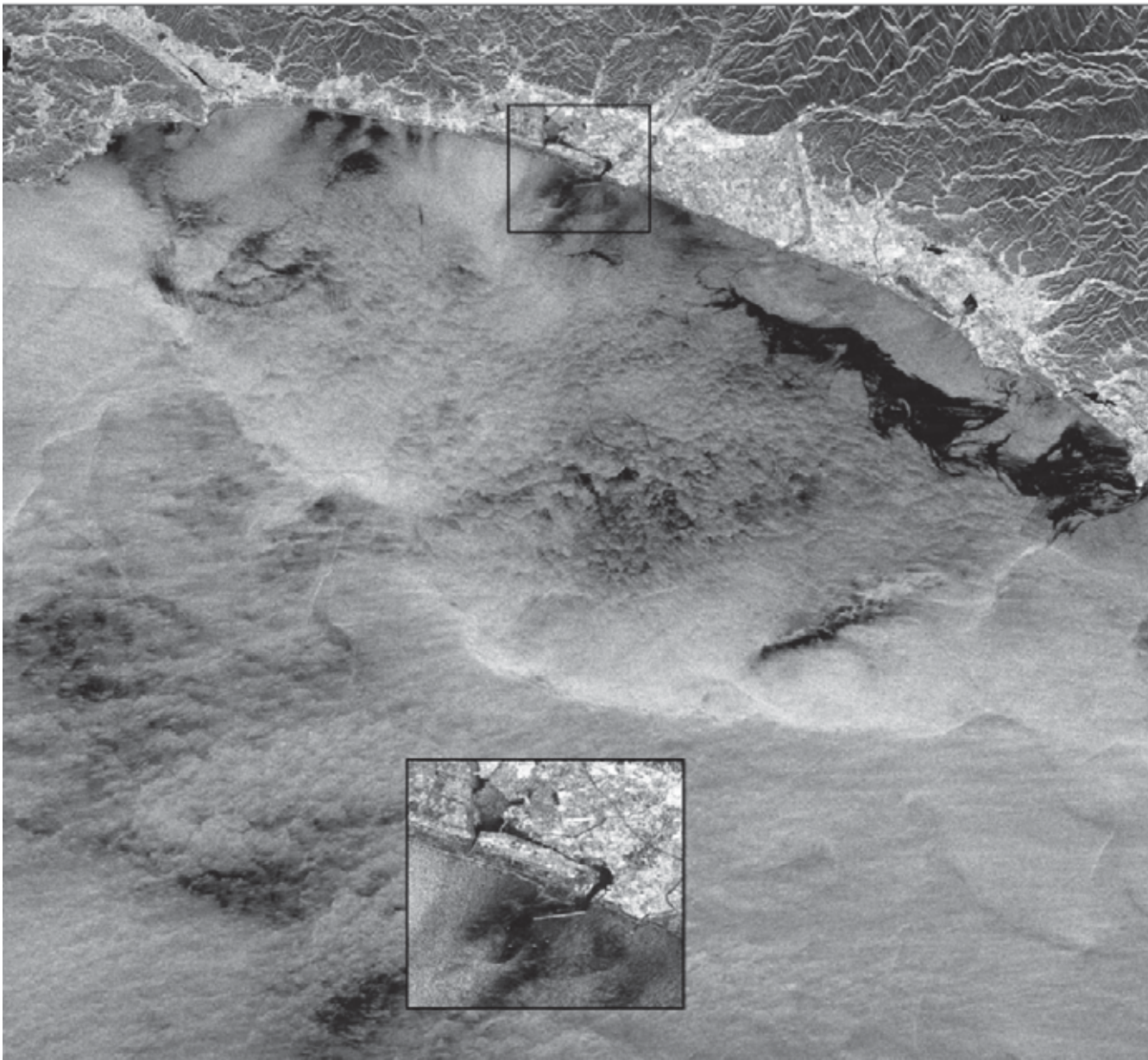
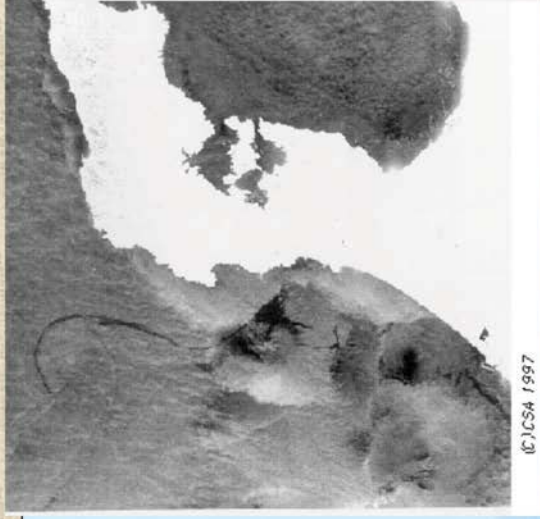


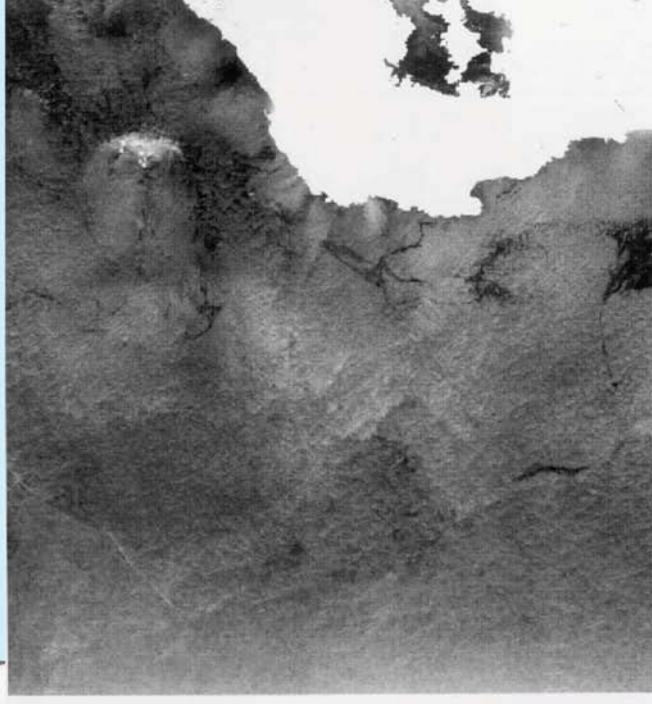
Figure C-2 RADARSAT View of the 1997 Nakhodka Oil Spill in Japan

*Note.* From "Satellite Operations", 2002, by A. Mahmood, *RADARSAT-1 Disaster Watch Program*. Retrieved October 27, 2008, from [http://www.unescap.org/icstd/SPACE/documents/RWDM\\_Bangkok/Acrobat/CANADA-RADARSAT1-Mahmood.pdf](http://www.unescap.org/icstd/SPACE/documents/RWDM_Bangkok/Acrobat/CANADA-RADARSAT1-Mahmood.pdf)

## Satellite observed oil slicks after the Nakhodka oil spill in the Japan Sea



**January 10-11, 1997**



Source: *Japan Remote Sensing Agency, Canadian RADARSAT data*

Figure C-3 Nakhodka Oil Spill Images

Note. From Japan Society for the Promotion of Sciences, 2000, "Asian Science Seminar", *Transport of Pollutants in the Air and the Sea of East Asia*. Retrieved October 27, 2008, from [http://omg.riam.kyushu-u.ac.jp/~vsm/html/Lecture\\_20001025.pps](http://omg.riam.kyushu-u.ac.jp/~vsm/html/Lecture_20001025.pps)



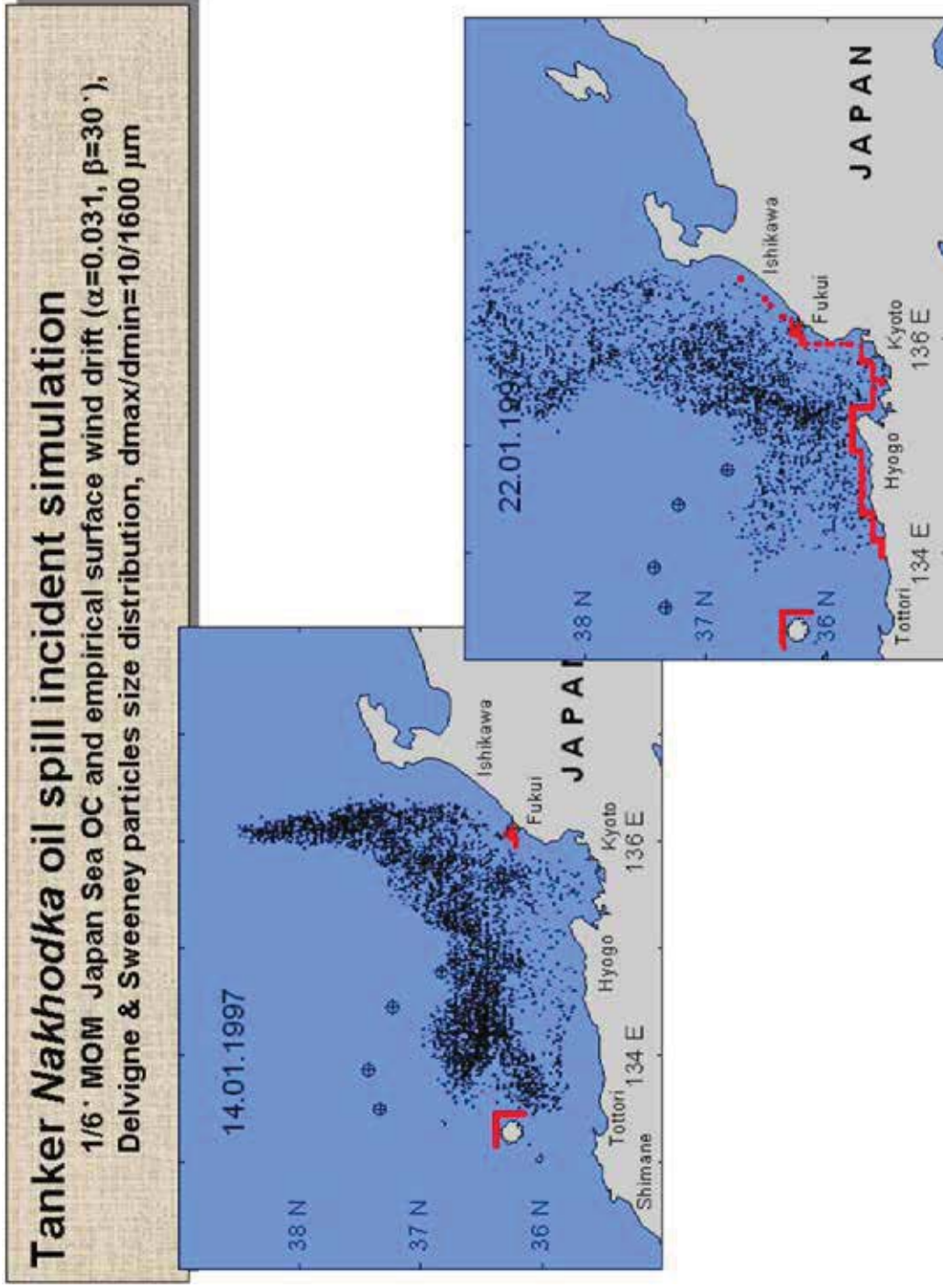


Figure C-4 Computer Simulation of the Nakhodka Oil Spill

Note. From Japan Society for the Promotion of Sciences, 2000, "Asian Science Seminar", *Transport of Pollutants in the Air and the Sea of East Asia*. Retrieved October 27, 2008, from [http://omg.riam.kyushu-u.ac.jp/~vsm/html/Lecture\\_20001025.pps](http://omg.riam.kyushu-u.ac.jp/~vsm/html/Lecture_20001025.pps)





**ROYAL CANADIAN AIR CADETS**  
**PROFICIENCY LEVEL FOUR**  
**INSTRUCTIONAL GUIDE**



**SECTION 3**

**EO C440.01 – DESCRIBE MODEL ROCKETRY**

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Total Time: 60 min

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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of the figures located at Attachments A.

Photocopy the handouts located at Attachments B and C for each cadet.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for this lesson to present basic information on model rocketry, and summarize the teaching points.

---

**INTRODUCTION**

---

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to describe the parts of a model rocket, the flight profile of a model rocket, and model rocket safety.

**IMPORTANCE**

It is important that the cadets know the parts of a model rocket, how a model rocket engine works, and model rocket safety, so they can plan the flight profile of their model rocket.

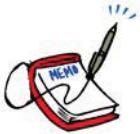
**Teaching Point 1****Describe the parts of a model rocket engine.**

Time: 15 min

Method: Interactive Lecture

Model rocket engines are composed of six basic parts:

- engine case,
- clay nozzle,
- black powder propellant,
- delay composition,
- ejection charge, and
- igniter.



Show the cadets the slide of Figure A-1 located at Attachment A.

**ENGINE CASE**

The case keeps the engine together and under the correct pressure. Without pressure, the fuel will burn without producing efficient thrust. If the case is not strong enough and the pressure gets too high, the engine will explode. The engine case can be made of paper, cardboard, plastic or aluminum. Paper cases are rolled from paper to form a solid tube of cardboard.

**CLAY NOZZLE**

The nozzle directs the gas that is formed by the reaction of the oxidant out the back of the rocket. The nozzle is formed so the gasses are accelerated as they pass through the nozzle and provide efficient thrust. Nozzles can be made of clay, ceramic or metal.

**PROPELLANT**

The propellant is the substance that actually burns or oxidizes. This reaction between the oxidizer and fuel generates gas and heat, which provides the power for the rocket.

Model rocket engines use black powder as both the oxidizer and fuel. The black powder is mixed with other components and is packed or molded into a solid form inside the engine case. These engines are easy to use and safe to transport because the components do not require special containers and the engines are very unlikely to ignite accidentally.

The propellant burns at a prescribed rate and propels the rocket through the atmosphere. The propellant burns stronger at takeoff and has less force towards the end of the power stage. This can be represented in a time-to-thrust graph.



Show the cadets the slide of Figure A-2 located at Attachment A.

Average thrust is calculated by dividing the total impulse by the duration of the propellant burning.

Depending on the depth of the igniter hole, rocket engines can burn two different ways. Shallow holes in the propellant result in end burn where the propellant burns from one end to the other. Engines requiring more lift use deep holes in the propellant causing the fuel to burn quickly resulting in extra lift earlier on in the flight.



Show the cadets the slide of Figure A-3 located at Attachment A.

Model rocket engines are labelled with a three-part classification code (B6-4) that describes the performance parameters of the engine. This code must be understood in order to choose the proper engine for the model rocket. The first part of the engine code is a letter designating the motor's total impulse class (the "B" in B6-4). Engine size is determined by the amount of propellant and case size. As engine size increases, the letter in the engine code changes to the next letter of the alphabet, and the engine is twice as powerful as the previous letter (eg, A series engines have 1.26 to 2.5 Newton seconds of force and B series engines 2.5 to 5 Newton seconds of force). Total impulse is the total power the engine produces. Total impulse is a measure of the momentum change the engine can impart to the rocket, measured in Newton-seconds. An engine with greater total impulse can lift a rocket higher and faster, and can lift heavier rockets, than an engine with lower total impulse. The table below gives the total impulse ranges and typical rocket performance for each class.



Show the cadets the slide of Figure A-4 located at Attachment A.

## THE DELAY COMPOSITION

After the propellant has burned entirely the delay composition starts burning to allow the rocket to coast to the highest point in the flight or the apogee. As the delay composition burns, it emits smoke, allowing tracking of the rocket in its flight. Delay composition burn times can vary from 3–10 seconds and are linked to the weight and size characteristics of the rocket. A heavy and slow rocket would require a shorter burn time, as it would not be moving through the air as fast as a smaller lighter rocket with the same code engine. It is important to calculate the delay as deployment of the parachute or streamer during high speed before or after apogee can result in destruction of the parachute or streamer.

## EJECTION CHARGE

The parachute or streamer is deployed by the ejection charge. This black powder charge ignites immediately after the delay composition has completed burning. It pushes the parachute or streamer and nose cone out of the front of the rocket.

## IGNITER

The igniter uses an electrically activated fuse to ignite the propellant. An electrical source supplies power to the control panel and control switch. Switching on the power at the control switch causes the igniter to burn, which ignites the propellant.

---

## CONFIRMATION OF TEACHING POINT 1

### QUESTIONS:

- Q1. The engine case of a model rocket engine can be made from what materials?
- Q2. Why does a model rocket require an ejection charge?
- Q3. How does an igniter work?

### ANTICIPATED ANSWERS:

- A1. Paper, cardboard, plastic or aluminum.
- A2. To deploy the parachute or streamer.
- A3. Switching on the power at the control switch causes the igniter to burn, which ignites the propellant.

---

## Teaching Point 2

## Describe the parts of a model rocket.

Time: 10 min

Method: Interactive Lecture

A model rocket consists of the following parts:

- nose cone,
- body tube,
- fins,
- launch lug,
- engine stop,
- engine restraint,
- shock cord, and
- parachute.



Show the cadets the slide of Figure A-5 located at Attachment A.

## NOSE CONE

The nose cone helps the rocket cut through the air during flight. It is important that the nose cone be aerodynamic to offer the least resistance when moving through the air. There are several different styles of nose cones, some for specific speeds. The nose cone is fitted to the body tube so that it can easily be ejected to deploy the parachute. It has an attachment point on one end for the shock cord and can be made from plastic, wood, Styrofoam™, fiberglass or carbon fibre.

## **BODY TUBE**

All the parts of the rocket attach to or are contained within the body tube. The tube must be rigid to maintain its form during flight and can be made of cardboard, plastic, fibreglass or carbon fibre.

## **FINS**

The fins help stabilize the rocket during flight. They are usually placed near the engine and are usually made of balsa wood, plastic, cardboard, fibreglass or carbon fibre. They must be attached securely and accurately to the body tube as any misalignment will result in an unpredictable flight. Fins on a rocket should be handled with care to avoid damage and misalignment.

## **LAUNCH LUG**

The launch lug guides the rocket off the launch pad for the first metre of flight until the rocket has reached enough speed for the fins to stabilize the rocket. In order to launch the rocket the launch lug is placed on the launch rod of the tower. The lug slides the rocket down the launch rod and is held there until launch. When the launch button is pressed, the rocket engine accelerates the rocket up the launch rod guided by the lug and can quickly achieve over 50 km / h before it leaves the launch rod. The lug can be made of cardboard or metal.

## **ENGINE STOP**

The engine stop prevents the engine from being pushed through the body tube by the engine's thrust. The engine stop is usually made of cardboard.

## **ENGINE RESTRAINT**

The restraint keeps the engine from being ejected out the tail of the rocket by the parachute deploying an explosive charge. Restraints can be a metal strap, screws or strong tape.

Both the engine stop and restraint prevent the effects of Newton's third law: for every action there is an equal and opposite reaction.

## **SHOCK CORD**

The ejection of the parachute must happen when the rocket reaches apogee or the highest point in the flight. The shock cord, made from elastic webbing, absorbs the force of the explosion that ejects the parachute. One end of the shock cord is attached to the nose cone, the other end to the body tube and the parachute is attached to the nose cone or the middle of the shock cord.

## **PARACHUTE**

The descent of the rocket must be controlled to avoid damage to people, property or the rocket. There are several ways to slow the descent of the rocket. The most common is the parachute, which traps air in a canopy to slow the decent. Parachute canopies are made of light flexible sheet material, in the form of a cross or circle. Shroud lines are made of string or cord, with one end attached to the edges of the canopy and the other end of the shroud lines are attached together to the shock cord or nose cone. Parachute sizes and shroud line length are carefully calculated to control the descent. A large parachute will allow the wind to carry the rocket far from the launch tower. A parachute that is too small will cause the rocket to descend too quickly, possibly causing damage to the rocket.

Other forms of descent can be used on different rockets. Streamers can be used with lightweight rockets and act as a drag on the rocket. Free fall can only be used by the lightest rockets and has no additional equipment to slow the rocket. The drag from the rocket's body and fins will slow the rocket. Glide recovery involves attaching a wing to the rocket to allow the rocket to glide to the Earth.

---

## CONFIRMATION OF TEACHING POINT 2

### QUESTIONS:

- Q1. What purpose does the nose cone serve?
- Q2. What does the launch lug do?
- Q3. How do the fins affect the flight of the rocket?

### ANTICIPATED ANSWERS:

- A1. It helps the rocket cut through the air.
- A2. It guides the rocket off the launch pad.
- A3. The fins stabilize the rocket during flight.

---

## Teaching Point 3

## Describe the flight profile of a model rocket.

Time: 10 min

Method: Interactive Lecture

The burn stages of a model rockets engine allow one to predict the flight profile of the rocket. The flight profile of a model rocket consists of six stages:

1. ignition,
2. power,
3. coast / delay,
4. ejection,
5. descent, and
6. landing.

### IGNITION

Ignition is the result of an electrical current lighting from the control panel and launch switch. The actual device that starts the engine burning is the igniter. It looks like a match head with wires coming from the tip. When the electrical current passes through the igniter, it heats up, causing it to burst into flame. This flame is what actually starts the propellant burning in the rocket engine.



Show the cadets the slide of Figure A-6 located at Attachment A.

After ignition, the rocket will leave the launch tower under thrust. The launch tower guides the rocket during low speed to ensure the rocket remains aligned on the prescribed course. The stabilizer fins on the rocket take over as it leaves the launch rod on the tower, usually at around 50 km / h.





Show the cadets the slide of Figure A-7 located at Attachment A.

## POWER

The propellant inside the engine burns quickly. In most engines, the propellant is consumed in less than three seconds, at which point burnout occurs. This means the engine is no longer producing a thrust force. By the time the engine burns out, the rocket has already reached its top speed and begins decelerating. While the rocket may reach hundreds of metres in the air, the burnout location on most rockets is about 15–25 m (50–80 feet) in the air.



Show the cadets the slide of Figure A-8 located at Attachment A.

## COAST / DELAY

When the engine burns out, the rocket may be travelling hundreds of kilometres per hour. The parachute or streamer can be destroyed if it is ejected at this speed. The model will coast upward and lose airspeed as gravity and air friction slow it down. The period of time that starts at engine burnout and ends when the parachute is ejected out of the rocket is called the coast phase. The delay composition is now burning at a prescribed rate and produces smoke. The rocket moves so fast, that it is hard to follow visually and the smoke helps give a visual indication of the location of the rocket.



Show the cadets the slide of Figure A-9 located at Attachment A.

## EJECTION

When the delay composition is done burning, the rocket should be at apogee. As the delay composition finishes burning it ignites the ejection charge. This ejection charge burns quickly, and is directed forward inside the rocket body tube. Its goal is to push off the nose cone, and eject the parachute out of the rocket. Ejection should occur right at apogee when the rocket has reached its slowest speed. Engine selection controls when the ejection charge pushes out the parachute. If the delay composition burns too long, the rocket will arc over, and will eject the chute while the rocket has begun accelerating in free fall descent. If the delay composition burns too quickly, the rocket may still be moving too fast as it has not coasted to its highest point. Ejection of the parachute at any point other than at apogee will result in the rocket and / or parachute being destroyed and the rocket free falling.



Show the cadets the slide of Figures A-10 and A-11 located at Attachment A.

**DESCENT**

After the parachute has ejected, it fully inflates, and the rocket begins its descent phase. The rocket drifts slowly to the ground under the canopy of the parachute or drag of the streamer. The wind will affect the descent of the rocket and this will result in the model drifting away from the launch pad. Descent should not be more than 4.5 m / s (15 feet per second) or it is possible to damage the rocket. If the descent is too slow, the rocket will drift farther from the launch pad affecting recovery.

**LANDING**

After landing, the rocket should be fully inspected before the next launch. The engine case should be discarded.



Show the cadets the slide of Figure A-12 located at Attachment A.

**CONFIRMATION OF TEACHING POINT 3****QUESTIONS:**

- Q1. How is a model rocket tracked during its flight?
- Q2. When is the optimum time during a rocket's flight profile to deploy the parachute or streamer?
- Q3. Why is there a delay or coast phase during the rocket's flight?

**ANTICIPATED ANSWERS:**

- A1. The smoke emitted by the delay composition and parachute or streamer can track the flight of a rocket.
- A2. At apogee.
- A3. To allow the rocket to slow down enough to deploy the parachute without destroying it.

**Teaching Point 4****Explain model rocketry safety rules.**

Time: 15 min

Method: Interactive Lecture

The hobby of model rocketry originated at the dawn of the space age in the late 1950s. Seeing space boosters carry the first artificial satellites into Earth's orbit inspired many enthusiastic young people to try to emulate the rocket pioneers by building their own rockets. Unfortunately, these homemade rockets involved stuffing flammable chemicals into metal pipes, very often with tragic results. Newspapers told stories of fingers and eyes lost and all too frequently of lives lost.

What was needed was a safe alternative that would allow young people to experience constructing and launching their own rockets and provide them with the opportunity to explore the science of rocketry.

Several companies developed engines that did not explode and provided a safe flight for model rockets. This style of engine is still in use today.

Safety is important when flying model rockets. It is impossible to get out of the way of a rocket going over 400 km / h. The flame produced by the engine is extremely hot and capable of inflicting serious burns or setting objects on fire. Therefore, there are rules in place for launching rockets. The Canadian Aviation Regulations (CARs) and the Canadian Association of Rocketry (CAR) have rules for launching model rockets.



Distribute photocopies of Attachments B and C to the cadets.

The CARs establish that a model rocket equipped with a model rocket engine will not have a total impulse exceeding 160 Newton-seconds and will not exceed 1500 grams, and will be equipped with a parachute or recovery device capable of retarding its descent. Anything above these parameters requires a high power model rocketry license and permission to fly from Transport Canada.

CAR model rocket rules cover launch site size, model rocket construction and launch procedures.

---

#### **CONFIRMATION OF TEACHING POINT 4**

##### **QUESTIONS:**

- Q1. Why is safety important when launching model rockets?
- Q2. Who establishes the rules for model rocketry in Canada?
- Q3. What is the maximum weight of a model rocket?

##### **ANTICIPATED ANSWERS:**

- A1. There are potential dangers from the rocket engine's flame and the high velocity of the rocket.
- A2. Canadian Association of Rocketry.
- A3. 1500 grams.

---

#### **END OF LESSON CONFIRMATION**

##### **QUESTIONS:**

- Q1. When do the fins help guide the rocket during its flight?
- Q2. How are rocket engines classified?
- Q3. How do we slow a rocket's descent?
- Q4. What purpose does the nose cone serve?
- Q5. What is apogee?

##### **ANTICIPATED ANSWERS:**

- A1. When the rocket achieves over 50 km / h or when it leaves the launch rod.
- A2. By letter, each successive letter doubles the force of the engine.
- A3. By using a parachute or streamer.
- A4. It helps the rocket cut through the air.
- A5. The highest point of a flight.

---

## CONCLUSION

---

### HOMEWORK / READING / PRACTICE

Nil.

### METHOD OF EVALUATION

Nil.

### CLOSING STATEMENT

Model rocketry is a fun and exciting sport. It is important to know the parts of a model rocket, how a model rocket engine works, model rocket safety, and how to plan the flight profile of a model rocket, to be able to fly model rockets safely.

### INSTRUCTOR NOTES / REMARKS

Cadets who have completed Advanced Aerospace summer training may assist with this instruction.

Cadets who are qualified Advanced Aviation may assist with this instruction.

---

## REFERENCES

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C3-162 Beach, T. (1993). *Model rocketry technical manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/roeketrytechniques.pdf>

C3-163 Cannon, R. L. (1999). *A learning guide for model rocket launch systems*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/launchsystemguide.pdf>

C3-259 ISBN 978-0471472421 Stine, G. H. (2004). *Handbook of model rocketry*. Toronto, ON: John Wiley & Sons.

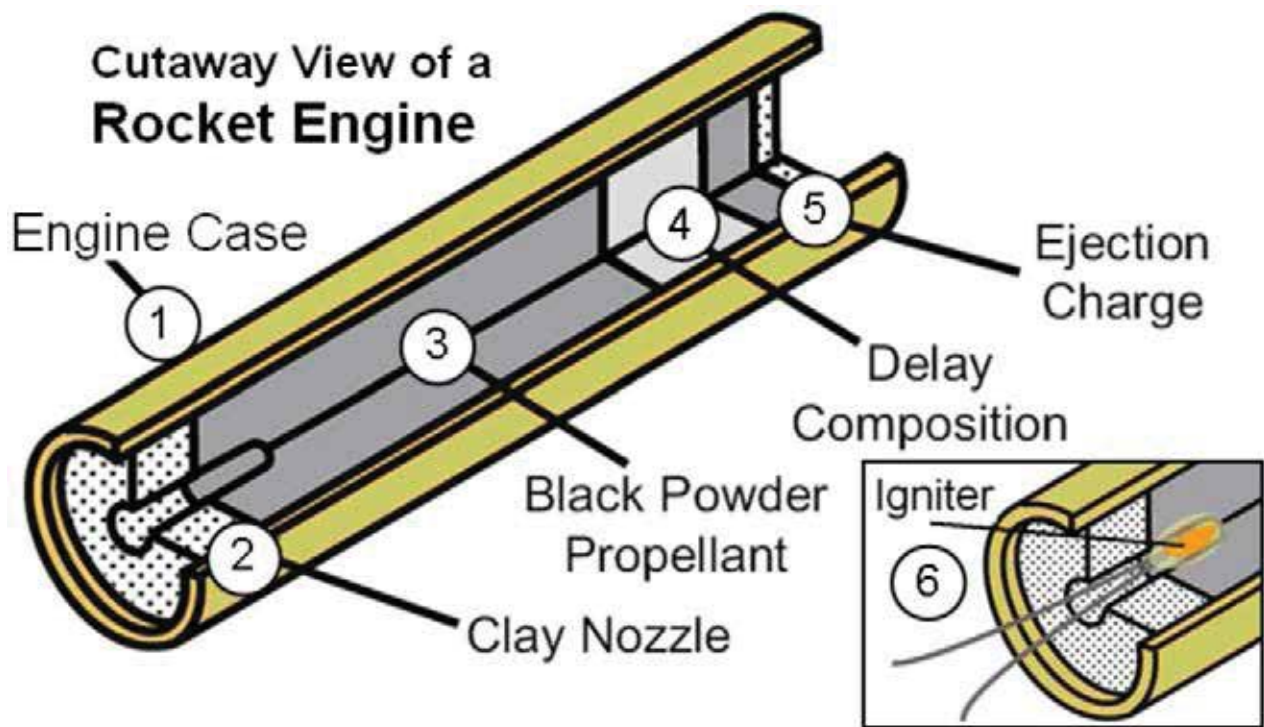


Figure A-1 Cutaway View of a Rocket Engine

Note. From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>

# TIME/THRUST CURVES

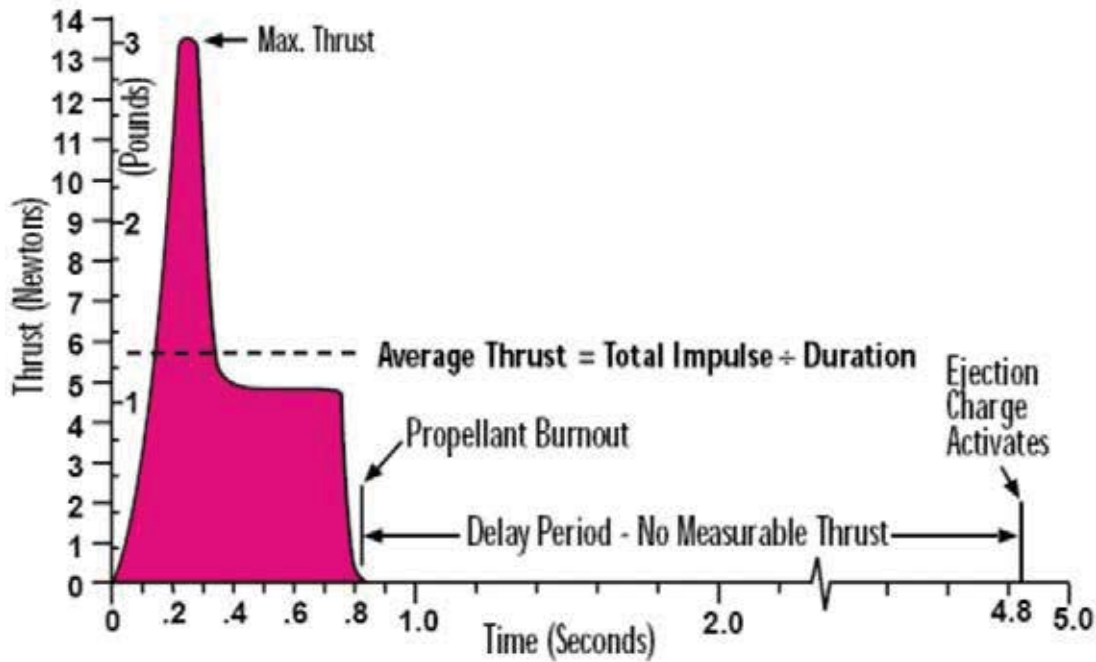


Figure A-2 Time / Thrust Curves

Note. From "Estes Rocketry", 1993, by T. Beach, 2003, *Model Rocketry Technical Manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/rocketrytechniques.pdf>



## ENGINE CODING FOR QUICK-N-EASY IDENTIFICATION

1. Label color indicates recommended use of the engine.
  - a. Green ..... Single Stage rockets
  - b. Purple ..... Upper Stage or Single Stage, if used in very light rockets
  - c. Red ..... \*Booster and intermediate stages of multi-stage rockets
  - d. Black ..... \*Special plugged engines for R/C gliders

\*These contain no delay or ejection charge.
2. Code designation stamped on the engine gives useful and important information on its performance capabilities.
  - a. This portion indicates total impulse or total power produced by the engine.
  - b. This portion shows the engine's average thrust in Newtons and helps you choose the proper engine for your rocket's flight.
  - c. This number gives you the delay in seconds between burnout and ejection charge. It lets you choose the engine with the delay time you want for any flight.

TYPE AND PRIMARY USE

**B6-2 SINGLE STAGE**




Figure A-3 Model Rocket Engine Codes

Note. From "Estes Rocketry", 1993, by T. Beach, 2003, *Model Rocketry Technical Manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/roeketrytechniques.pdf>

## TOTAL IMPULSE CLASSIFICATION

Code	Pound-Seconds	Newton-Seconds
1/2A	0.14 - 0.28	0.625 - 1.25
A	0.28 - 0.56	1.26 - 2.50
B	0.56 - 1.12	2.51 - 5.00
C	1.12 - 2.24	5.01 - 10.00
D	2.24 - 5.00	10.01 - 20.00

Figure A-4 Impulse Classification for Model Rocket Engines

*Note.* From "Estes Rocketry", 1993, by T. Beach, 2003, *Model Rocketry Technical Manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/roeketrytechniques.pdf>

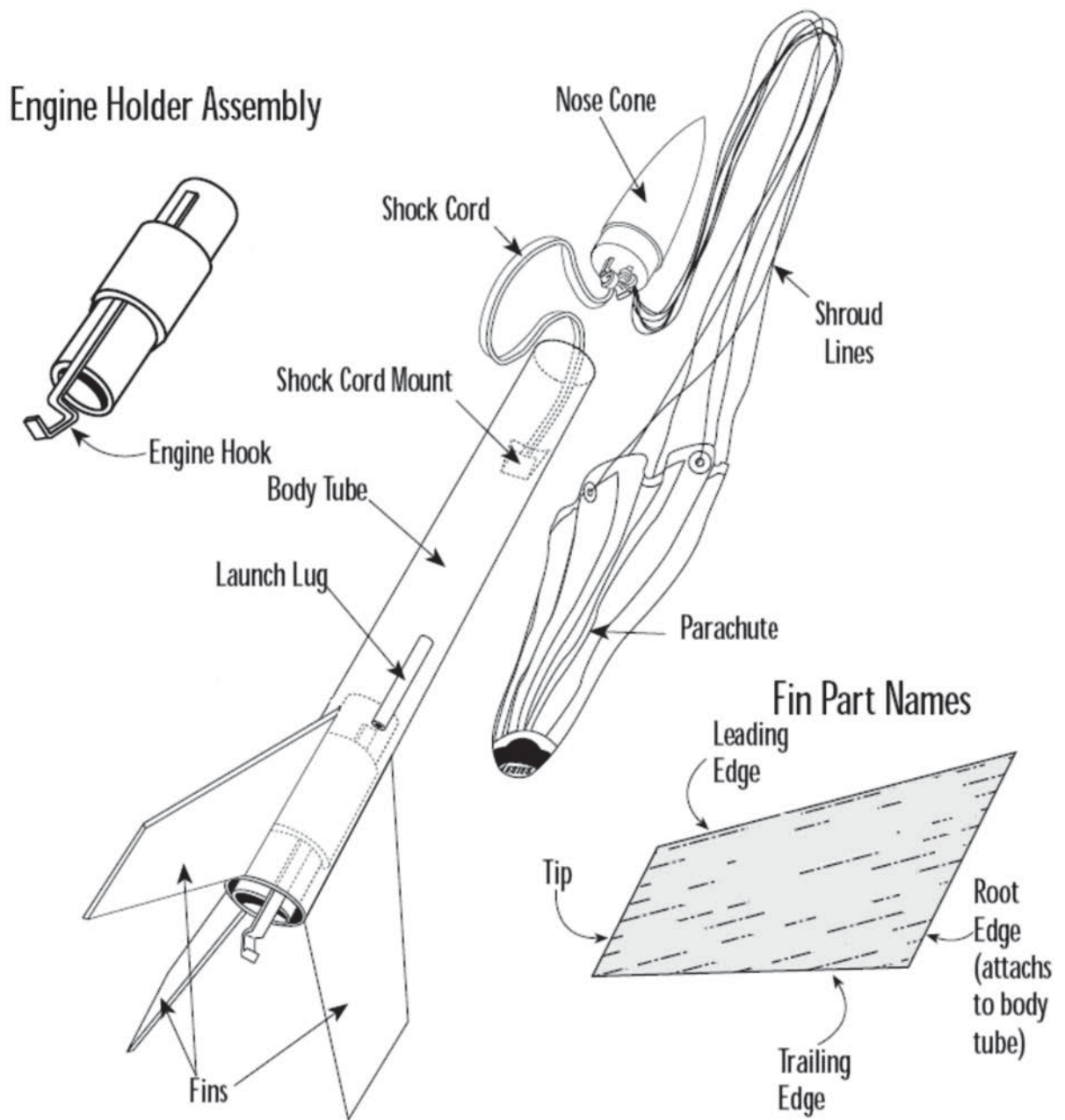


Figure A-5 Parts of a Model Rocket

Note. From "Estes Rocketry", 1993, by T. Beach, 2003, *Model Rocketry Technical Manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/rocketrytechniques.pdf>

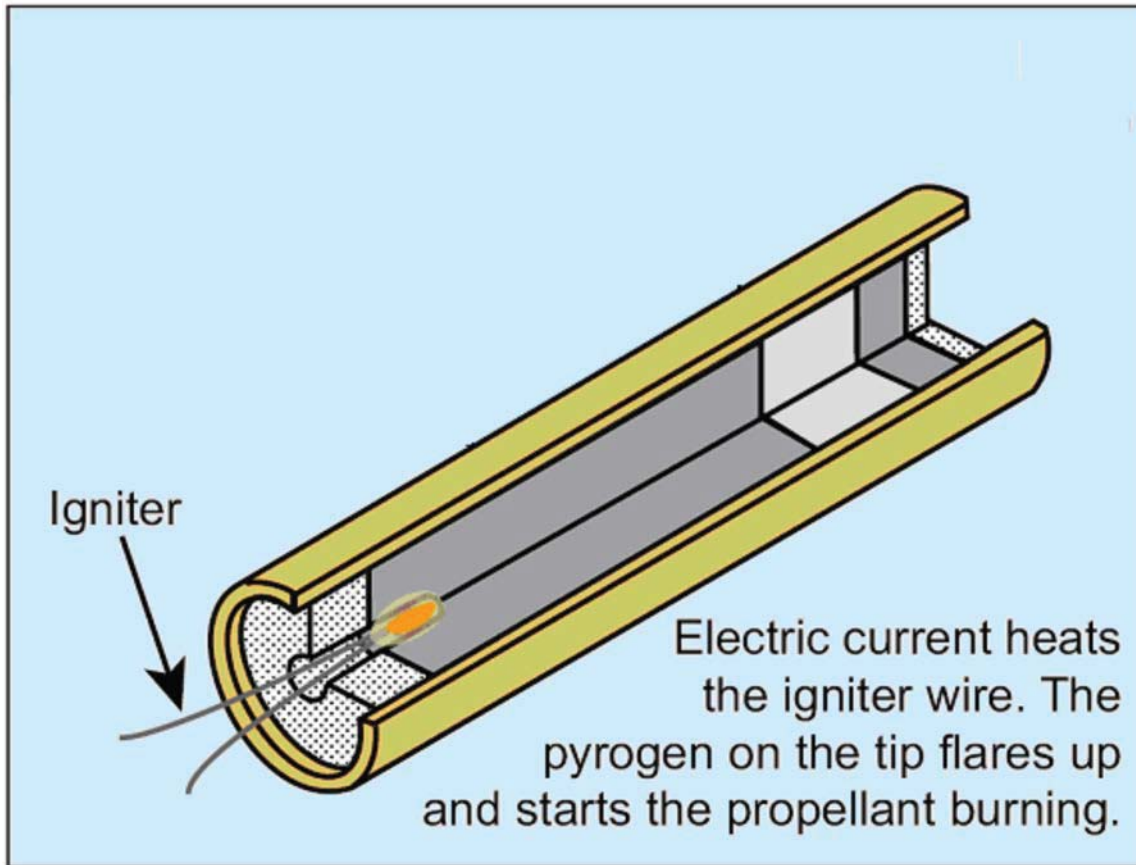


Figure A-6 The Igniter

Note. From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>

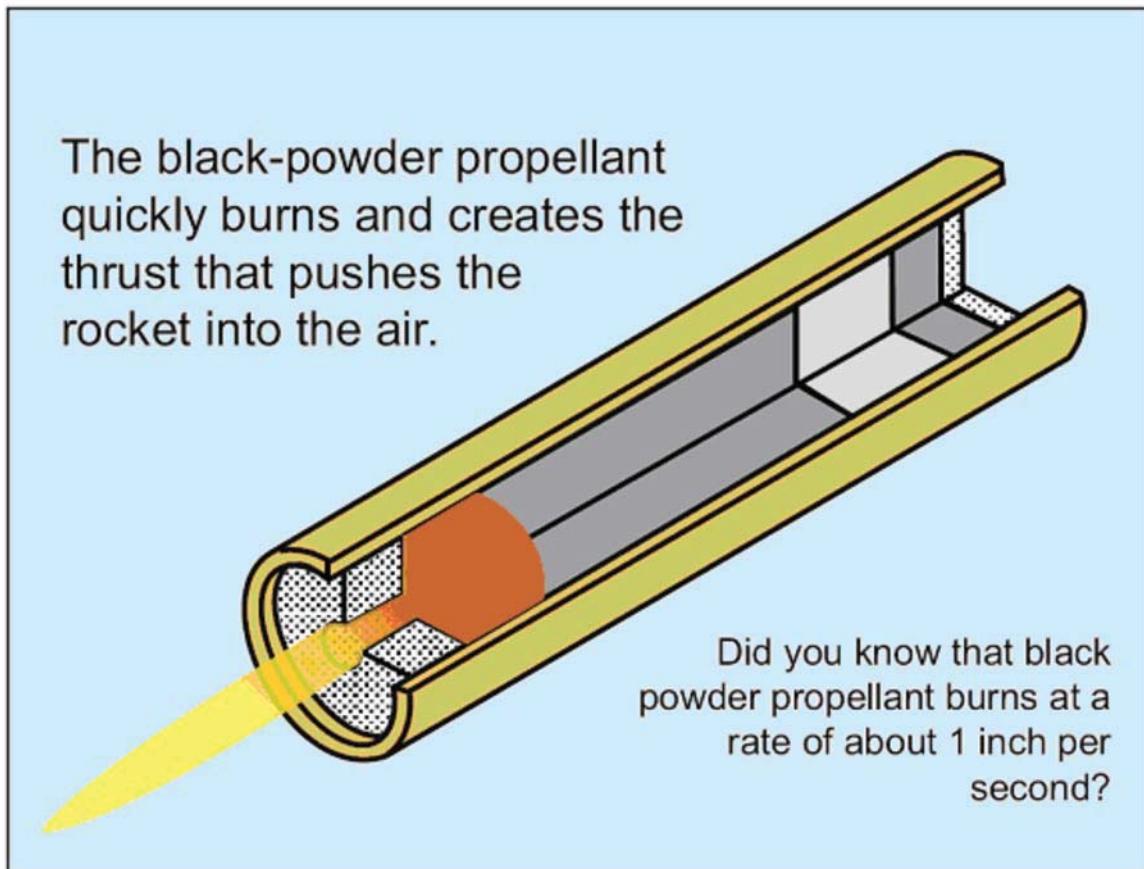


Figure A-7 The Propellant Ignited

*Note.* From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>

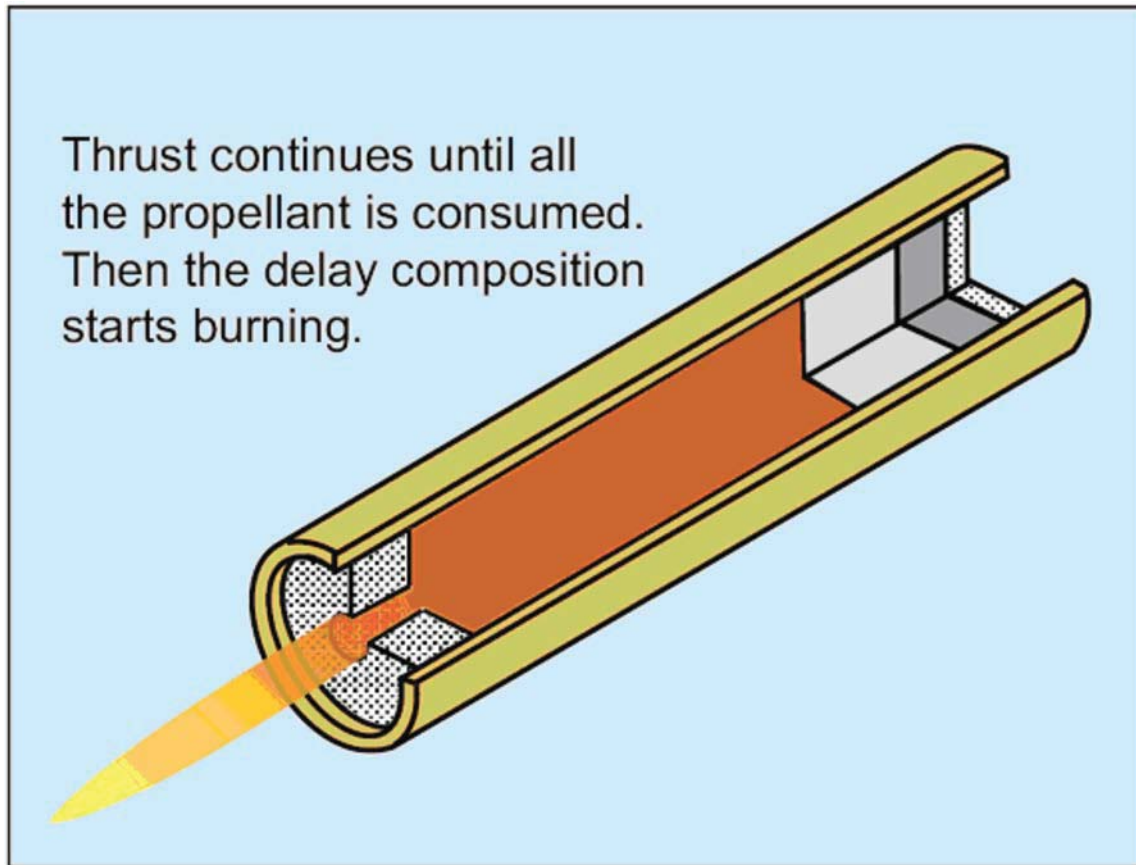


Figure A-8 Thrust Phase

Note. From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>



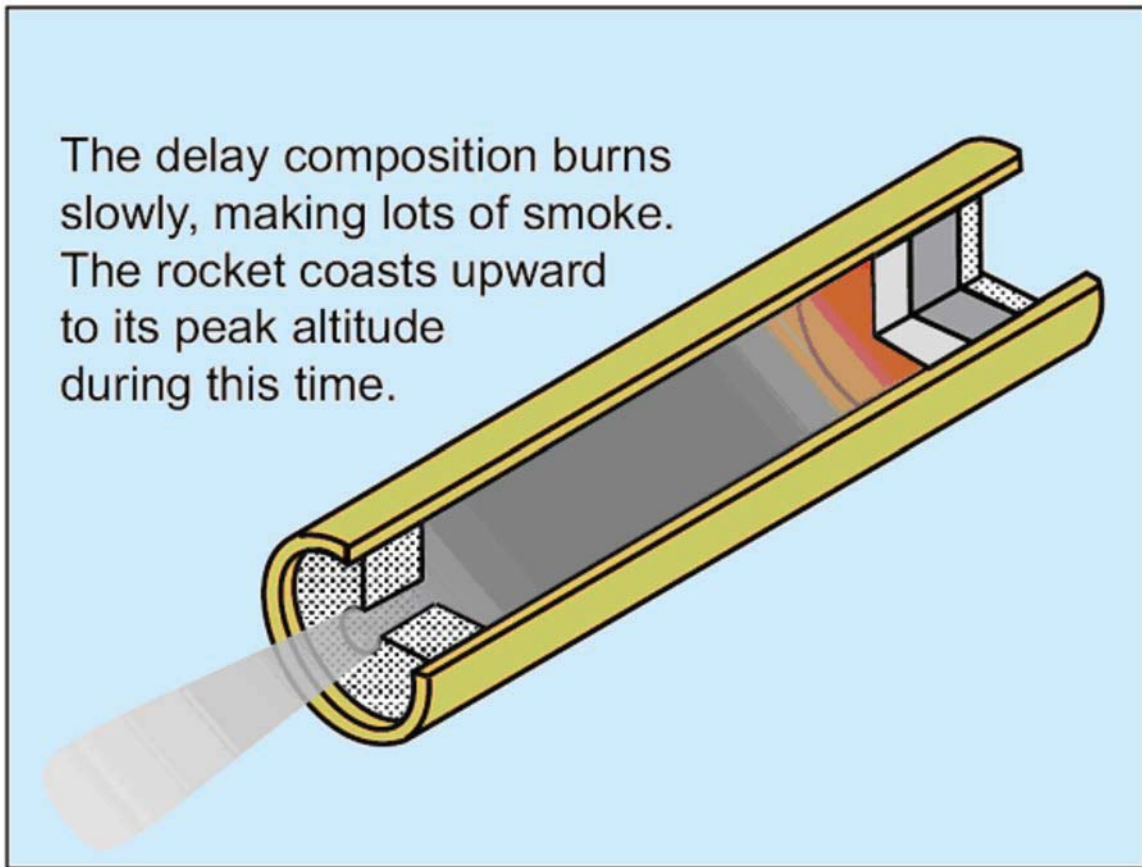


Figure A-9 Delay or Coast Phase

*Note.* From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>

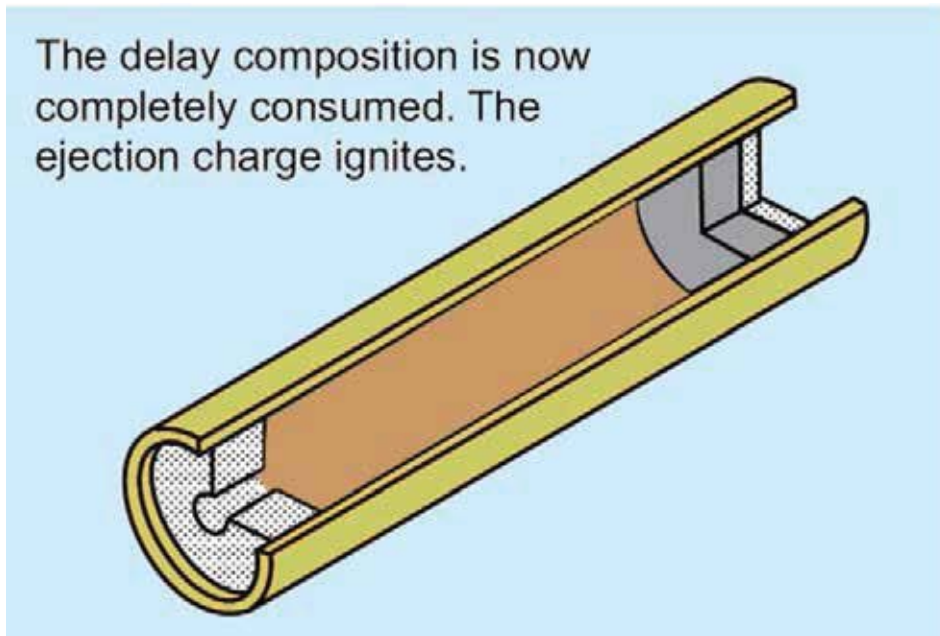


Figure A-10 Beginning of the Ejection Phase

Note. From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>

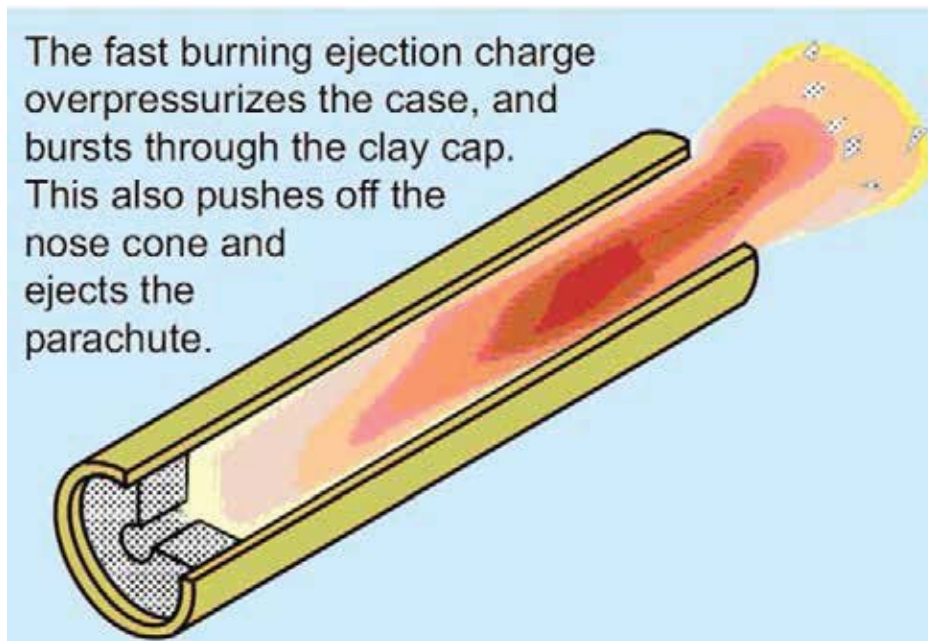


Figure A-11 Ejection Phase

Note. From "Apogee Peak of Flight Newsletter", 2003, *How Black Powder Rocket Motors Work*. Retrieved November 16, 2007, from <http://www.apogeerockets.com/educator/downloads/newsletter114.pdf>

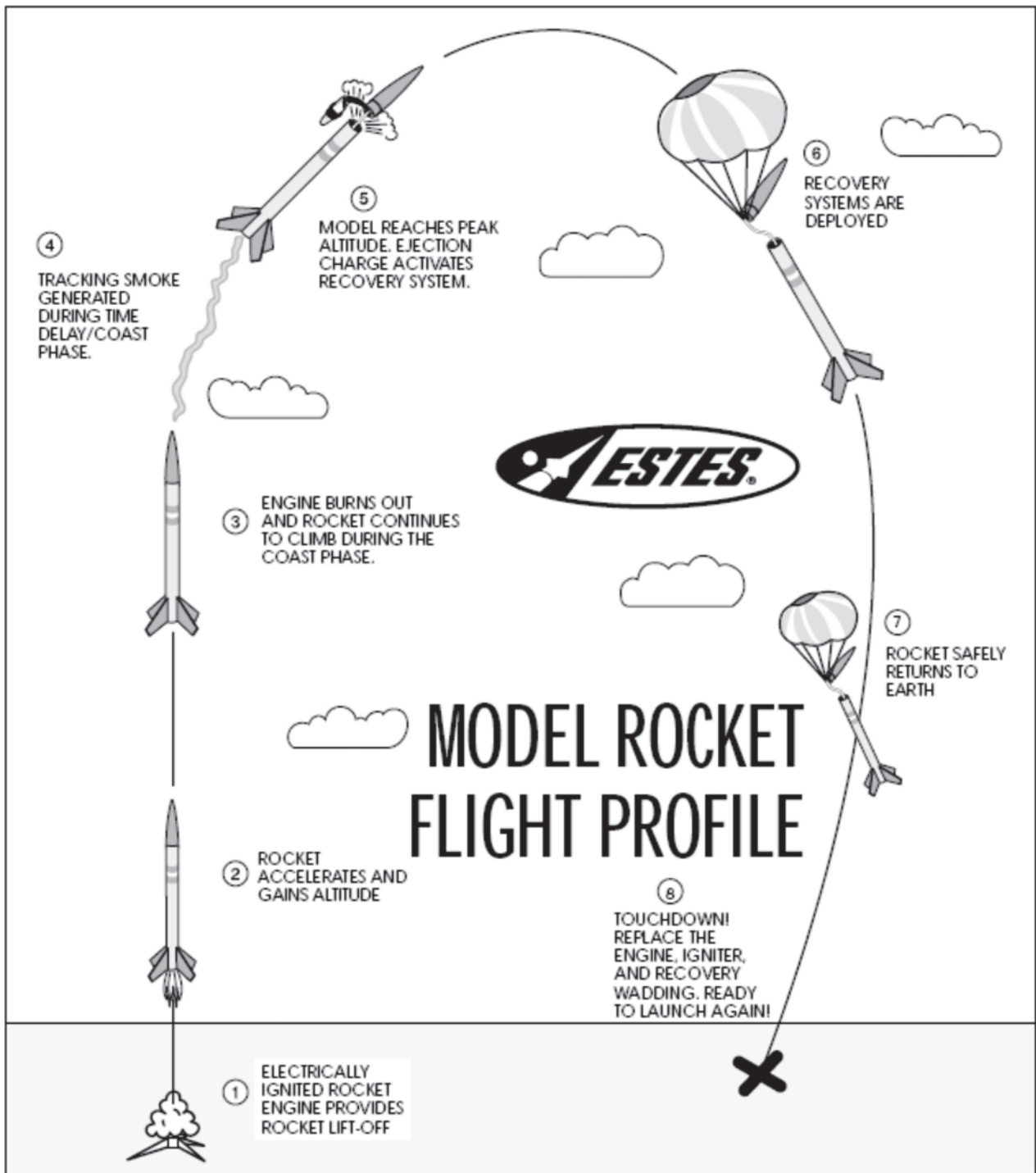


Figure A-12 Model Rocket Flight Profile

Note. From "Estes Rocketry", 1993, by T. Beach, 2003, *Model Rocketry Technical Manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/rocketrytechniques.pdf>

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## CANADIAN ASSOCIATION OF ROCKETRY: CANADA MODEL ROCKET SAFETY CODE

1. **CONSTRUCTION:** I will always build my model rocket using only lightweight materials such as paper, wood, plastics and rubber without any metal airframe components. My model shall include aerodynamic surfaces or a mechanism to assure a safe, stable flight.
2. **ENGINES:** I will use only pre-loaded, commercially available model rocket engines approved safe by Energy, Mines and Resources Canada. I will never subject these engines to excessive shock, extremes of temperature, nor will I ever attempt their reloading or alteration. I shall always employ recommended manufacturer handling and ignition procedures.
3. **RECOVERY:** My model rocket will always utilize a recovery system to return it safely to the ground so that my model rocket may be reflown. I shall prepare the recovery system with due care to assure that it will properly deploy.
4. **WEIGHT LIMITS:** My model rocket will not weigh more than 1500 grams at liftoff and the model rocket engine(s) will contain no more than 125 grams of propellant.
5. **FIRING SYSTEM:** I will always use a remote, electrical system to ignite the model rocket engine(s). My firing system will include an ignition switch that will return to "OFF" when released, and a safety interlock key switch to prevent accidental ignition. I will never leave the safety interlock key in my firing system between launches.
6. **LAUNCH SYSTEM:** My model rocket will always be launched from a stable platform having a device to initially guide its motion. My launch system will have a jet deflector to prevent the engine exhaust from directly contacting the ground, or inflammable launcher components. To protect others and myself from eye injury, I will position the launch rod or rail so that the upper end is above eye level, or else I will place a large guard on the upper end between launches. I will never place my body or hand directly over my loaded model rocket mounted on the launch system.
7. **LAUNCH SITE:** I will never launch my model rocket near buildings, power lines or within 9.1 kilometres from the centre of an airport. The area immediately around the launch system will be cleared of any flammable materials. I will always obtain the permission of the launch site owner prior to using the launch site for my model rocket activities.
8. **LAUNCH CONDITIONS:** I will never launch my model rocket in high winds or under conditions of low visibility that may impair the observation of my model rocket in flight, or in a direction below 30 degrees from the vertical.
9. **LAUNCH SAFETY:** I will remain at least five metres away from any model rocket about to be launched. I will always announce to persons within the launch site that I am about to launch my model rocket, and I shall give a loud countdown of at least five seconds duration. I shall immediately remove the safety interlock key from my firing system after the launch of my model rocket.
10. **MISFIRE:** In the event of an ignition misfire, I shall not immediately approach my model rocket, but remove the safety interlock key and remain back for a safe period until assured that no ignition will occur.
11. **ANIMAL PAYLOADS:** I will never endanger live animals by launching them in my model rocket.
12. **TARGETS:** I will never launch my model rocket so that it will fall on or strike ground or air targets, nor will I include any explosive or incendiary payload.
13. **HAZARDOUS RECOVERY:** I will never attempt to recover my model rocket from a power line, high place or other dangerous location.

14. PRE-FLIGHT TESTS: Whenever possible, I will, always test the stability, operation and reliability of my model rocket designs prior to flight. I will launch unproven designs in complete isolation from other persons.
15. PERSONAL CONDUCT: I will always conduct myself in a responsible manner, conscious that the maintenance of safety for others and myself rests with my ability to design and construct sound, working models, and to enthusiastically abide by the Canada Model rocket Safety Code.



2. CANADIAN ASSOCIATION OF ROCKETRY: MODEL ROCKET STANDARDS
  - 2.1 A "model rocket" is defined as a heavier-than-air flying rocket having a substantially non-metallic airframe, employing the reaction force of a model rocket engine as its sole source of lift and incorporating an automatically initiated system that will assure a safe descent and model reusability.
  - 2.2 The model rocket shall be constructed of wood, paper, plastic or similar lightweight materials. No substantial metal components shall be incorporated in the model rocket airframe.
  - 2.3 The model rocket shall embody aerodynamic surfaces and / or a guidance system, which will develop the necessary stabilizing and restoring forces to produce and maintain a safe, predictable and substantially vertical flight path. Model rockets, which employ an internally or externally controlled guidance system, shall incorporate sufficient inherent stability to fail safe any malfunction or disabling of the guidance system.
  - 2.4 The model rocket shall incorporate a reliable and effective means, of retarding its descent so that no hazard shall be presented to 'persons or property on the ground, and to prevent model damage upon touchdown so as to enable reflight. All engine casings and / or portions of the model jettisoned from the model rocket during flight shall descend with a fully deployed streamer or parachute, or by aerodynamic surfaces, which will induce rapid tumbling or a shallow glide. Minimum loading requirements shall be five (5) square centimetres per gram for parachutes, and ten (10) square centimetres per gram for streamers.
  - 2.5 A model rocket shall utilize no more than three powered stages. A "powered stage" shall be defined as a unit of the whole model rocket airframe which contains one or more model rocket engines, and which is designed to and / or actually separates as a unit in flight after the burnout of its contained engine(s). The number of powered stages used shall be assessed from the staged model configuration at the instant of its first motion on the launcher.
  - 2.6 A model rocket incorporating a self-energized firing system shall contain a safety interlock switch that will disable the firing circuit when "OFF". Activation of the firing system shall occur only immediately prior to launch. The self-energized firing system shall include a safe and reliable provision to test circuit continuity.
  - 2.7 All combustible materials subject to high temperature developed by the function of any model rocket engine, burning-wick dethermalizer or other auxiliary devices operating at higher than 200 degrees Celsius shall be flame proofed or similarly protected to prevent their ignition. Any on-board device, which initiates ignition and / or employs combustion, shall be self-extinguishing upon termination of actual or intended function.
  - 2.8 A model rocket shall never contain an explosive or pyrotechnic payload, nor shall it be used to launch a living animal.
  - 2.9 The maximum or gross mass of a model rocket at launch shall not exceed 1500 grams.
  - 2.10 The model rocket shall contain no more than 125 grams of propellant grain.

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**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 4**

**EO C440.02 – LAUNCH A SMALL MODEL ROCKET**

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Total Time:	90 min
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**PREPARATION**

---

**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Locate a proposed launch site IAW the Launch Site Set-Up located at Attachment A.

Ensure that permission to launch a small model rocket has been received from airport authorities.

Ensure that written permission to use the launch location has been received from the property owner.

Perform a risk assessment of the launch location.

Practice rocket engine and igniter installation.

Assemble the rocket launch controllers and launch towers.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

A practical activity was chosen for this lesson as it is an interactive way to introduce the cadets to constructing and launching model rockets in a safe, controlled environment.

---

**INTRODUCTION**

---

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson, the cadet shall have launched a small model rocket.

**IMPORTANCE**

It is important for cadets to experience the thrill of launching a model rocket, as it will stimulate an interest in aerospace, model rocketry and the Air Cadet Program. Launching a small model rocket that they built themselves will also develop in cadets a sense of pride and accomplishment.

---

**Teaching Point 1****Demonstrate and have the cadets assemble a model rocket.**

Time: 25 min

Method: Practical Activity

---

**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets assemble a model rocket.

**RESOURCES**

- No. 11 hobby knives,
- Cement for plastic models,
- Scissors,
- Pencil, and
- Model rocket kit that utilizes an A-series engine.

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Familiarize the cadets with the parts of the rocket.
2. Distribute one model rocket kit to each cadet.
3. Demonstrate and have the cadets, in pairs, complete the steps in building a model rocket.

**SAFETY**

- Caution is required when using sharp tools.
- Provide adequate ventilation when using solvent-based glues.

---

**CONFIRMATION OF TEACHING POINT 1**

The cadets' participation in the activity will be the confirmation of this TP.

---

**Teaching Point 2****Have the cadets assist in the set-up of the rocket launch site.**

Time: 20 min

Method: Practical Activity

---



Have the cadets assist in the set-up of the rocket launch site IAW Attachment A.

---

## CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the activity will serve as the confirmation of this TP.

---

### Teaching Point 3

**Have the cadet launch a small model rocket.**

Time: 35 min

Method: Practical Activity

---

## ACTIVITY

### OBJECTIVE

The objective of this activity is to have the cadets launch the small model rockets assembled in TP 1.

### RESOURCES

- Preassembled model rockets from TP 1,
- Rocket launch site setup drawing located at Attachment A,
- Model rocket launching procedure located at Attachment B,
- Model rocket launch tower,
- Model rocket launch controller,
- 80 m of safety tape,
- 18 modular tent pegs or a suitable substitute,
- Safety glasses,
- Voltmeter,
- Pliers,
- Screwdriver, and
- Electrical tape.

### ACTIVITY LAYOUT

The rocket launch site will be set up IAW Attachment A.

### ACTIVITY INSTRUCTIONS

1. Follow the model rocket launching procedure located at Attachment B.
2. Have the cadets install the igniters in the rocket engines.
3. Have the cadets install the rocket engines in the rockets.
4. Have the cadets place the rockets on the launch pads.
5. Have the cadets press the launch buttons and launch their rockets.



6. Have the cadets track the rockets through its flight.
7. After the rockets have landed, have the cadets recover them.

**SAFETY**

- Ensure control of the entire rocket site at all times.
  - Only the instructor and the cadets launching the rockets will be in the launch control area.
  - Spectators will remain at least 20 m from the launch tower.
  - Engines should be kept in a steel box and only distributed when the rockets are ready to be launched.
  - Horseplay will not be tolerated at any time during the launching of model rockets.
  - Recovery should be done quickly as delay may prevent the launching of all the rockets.
- 

**CONFIRMATION OF TEACHING POINT 3**

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**END OF LESSON CONFIRMATION**

The cadets' participation in the small model rocket launch will serve as the confirmation of this lesson.

---

**CONCLUSION**

---

**HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

A model rocket is subject to the same forces and laws of nature as a space-program launch vehicle. Experience with model rockets will give the hobbyist useful space program insights.

**INSTRUCTOR NOTES / REMARKS**

EO C440.01 (Describe Model Rocketry) must also be selected and delivered prior to this lesson.

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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## REFERENCES

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C3-162 Beach, T. (1993). *Model rocketry technical manual*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/roeketrytechniques.pdf>

C3-163 Cannon, R. L. (1999). *A learning guide for model rocket launch systems*. Retrieved October 10, 2007, from <http://www.estesrockets.com/assets/downloads/launchsystemguide.pdf>

C3-259 ISBN 978-0-471-47242-1 Stine, G. H. (2004). *Handbook of model rocketry*. Toronto, ON: John Wiley & Sons.

## LAUNCH SITE SET-UP

1. A safety briefing will be held before the launch site is set up, covering the following points:
  - a. The Launch Control Officer (LCO) is the only person permitted to activate the launch control panel.
  - b. All launch systems will be placed in "safe" mode between each flight.
  - c. When a rocket is descending out of control, launch site personnel will point at the rocket and repeat the phrase "heads up" until the rocket has landed.
  - d. No horseplay will be tolerated.
  - e. A safe rendezvous point will be clearly indicated and in the event of an emergency, launch site staff will move all cadets and staff to this point.
  - f. The area required for launching model rockets should be at least 100 m square. It should not have any tall buildings, trees, power lines or other tall objects close by. The cadets and spectators should be located in an area at least 20 m from the launch towers. Bleachers at a baseball field or soccer field are suitable.
  - g. If the site is within 9 km (5.6 miles) from an aerodrome, the aerodrome must be advised of the date and time the rockets will be launched. The rocket can reach a height of 200–400 feet at apogee and can be flown safely from the suggested field size.
2. Wind will play an important factor in the rocket's recovery. The descending rocket will drift with the wind and if descending too slowly will land far from the launch site. Rockets should not be launched in winds stronger than 35 km / h (28 miles per hour).



If the first rockets launched descend too slowly resulting in the rockets landing far from the launch site, a hole can be cut in the centre of the parachute to speed up the rockets descent.

3. Layout the rocket launch site as per Figure A-1. Wind direction should be accounted for by placing the towers closer to the windward side of the field.
4. Using modular tent pegs or a suitable substitute as posts, cordon off a 10 m by 10 m security tape border around the launch towers and a 10 m by 10 m security tape border around the launch control site leaving a 1 m opening for access.
5. Assemble the launch towers as per directions included with the towers. Place the launch towers in a line perpendicular to the wind. The launch rods should point slightly into the wind.
6. Place the launch control panels on the launch control tables and run the wire from each of the launch control boxes to the launch towers ensuring the wires are not tangled and in good working order.
7. All rockets will be brought to the rocket holding area before the launch begins.
8. Make sure all the connections are clean and tight.

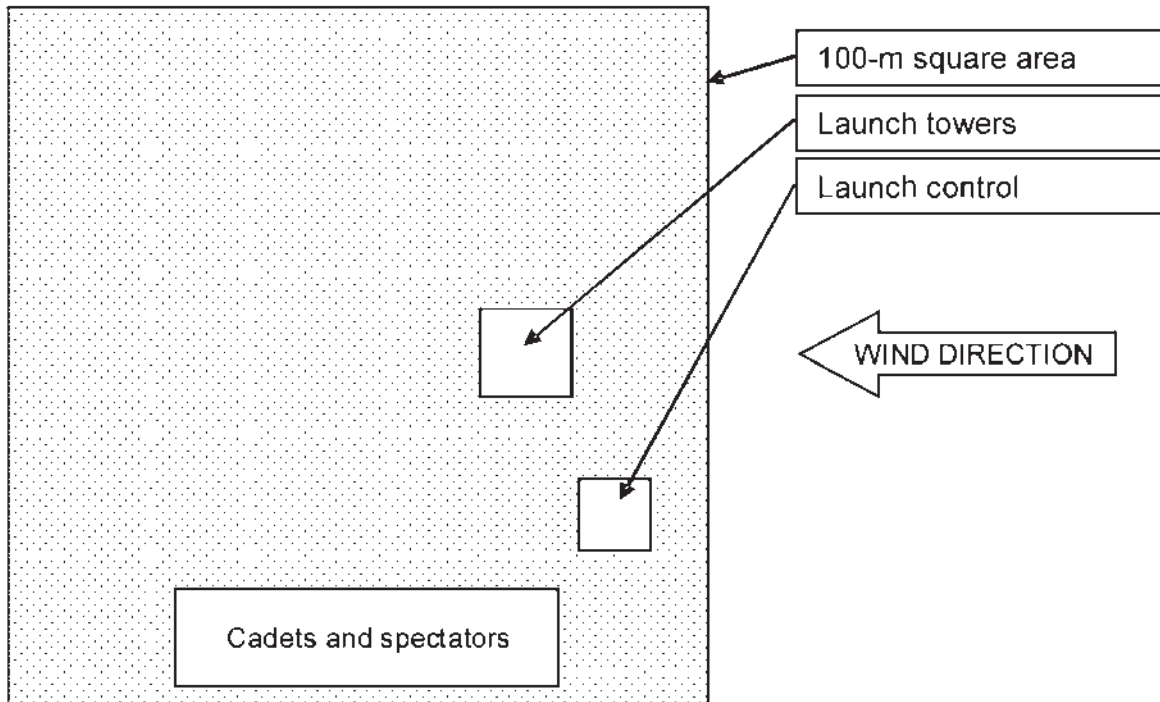


Figure A-1 Layout for a Rocket Launch Site

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

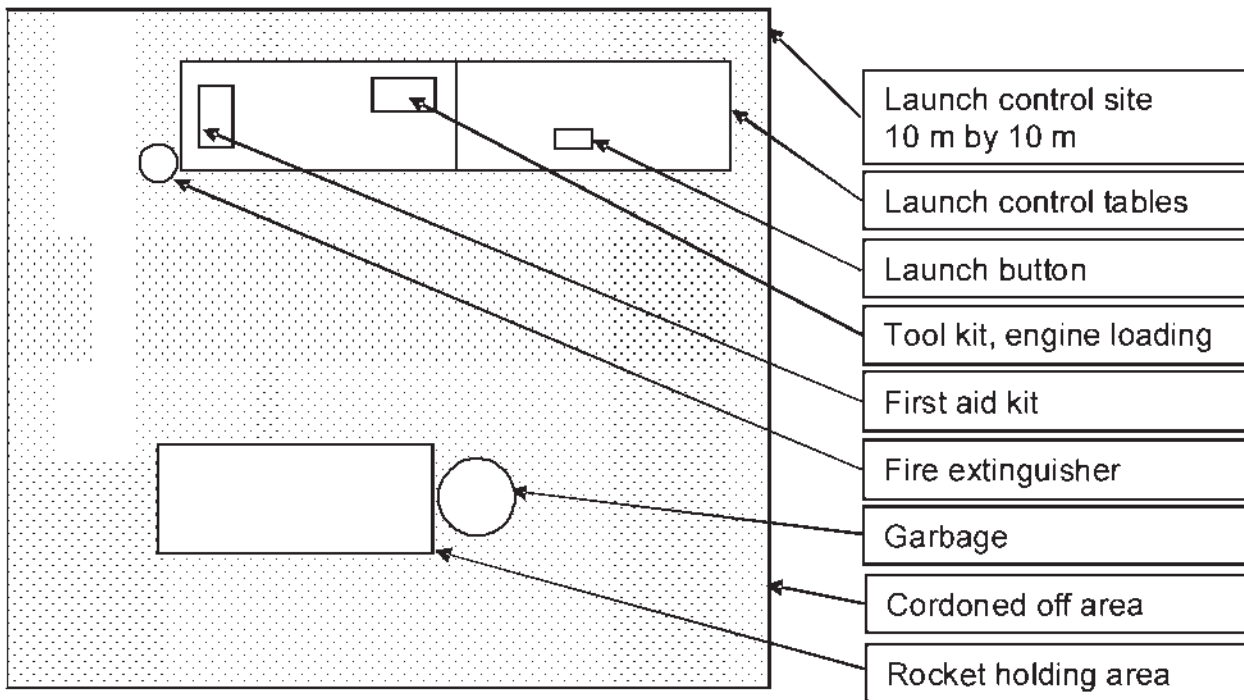


Figure A-2 Layout for a Launch Control

Note. Created by Director Cadets 3, 2008, Ottawa, ON: Department of National Defence.

## MODEL ROCKET LAUNCH PROCEDURE

1. Place the launch control switches in the safe position.
2. Collect the rockets from the cadets and prepare them for launch by following the directions included with the model rocket, launch control and launch towers.



The igniters should be handled with care, as damaged igniters are the cause of most misfires.

3. Following the launch tower directions, install one rocket on each launch tower.
4. Verify the launch control switches are in the safe position.
5. Connect the two alligator clips from each launch controller to the igniter leads on each of the rockets.
6. Make sure everyone stands back from the launch towers and have the cadets start a countdown from ten, backwards to zero.
7. Place the safe switches in the launch position.
8. Have the cadets press the launch buttons and launch their rockets.



If the rocket does not lift off the pad, wait at least one minute before approaching the pad. See Attachment C for troubleshooting the launch system.

9. Have the cadets track the rockets through their flights.
10. After the rockets have landed, allow the cadets to recover them.



After each flight, the alligator clips at the launch towers should be cleaned with 280-grit sandpaper and replaced when they can no longer be cleaned effectively.

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### **IF THE ROCKET ENGINE DOES NOT IGNITE**

1. Place the launch control button in the safe mode.
2. Wait one minute before approaching the launch tower. This will ensure the engine is no longer able to ignite.
3. Undo the alligator clips from the igniter and remove the rocket from the launch tower.
4. At the launch tower, test the power with a voltmeter to ensure there is voltage present by setting the voltmeter to "V" and placing the tower's alligator clips on the leads of the voltmeter, red to red and black to black.
5. With all the wires connected and the launch button pressed, the launch control lights should be on and the voltmeter should read approximately the voltage of the combined batteries (eg, three batteries at 1.5 volts each equals 4.5 volts).
6. If the lights on the launch control do not light or the voltmeter registers low voltage or no voltage at all, the batteries are weak or dead, one of the wires is broken, or there is a loose connection at the launch control or the launch pad.
7. To trace the problem, start at the launch control and ensure there are fresh batteries. If the batteries are fresh and correctly installed, proceed to the launch tower and verify if there is voltage at the launch tower. Repair any breaks in the wire or loose connections.
8. Verify that the igniter leads are not touching each other and that the igniter tip is not broken. If the igniter appears to be unserviceable, install a new igniter and restart the launch process.

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**ROYAL CANADIAN AIR CADETS**  
**PROFICIENCY LEVEL FOUR**  
**INSTRUCTIONAL GUIDE**



**SECTION 5**

**EO C440.03 – DISCUSS CHARACTERISTICS OF THE PLANETS IN THE SOLAR SYSTEM**

Total Time:

60 min

---

**PREPARATION**

---

**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy the Planets Specifications Sheet located at Attachment A for each cadet.

Create slides of Attachment B to be used in the end of lesson confirmation.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for this lesson to introduce the cadets to the characteristics of the planets in the solar system and to generate interest in the subject.

---

**INTRODUCTION**

---

**REVIEW**

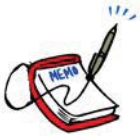
Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall have discussed the characteristics of the planets in the solar system.

**IMPORTANCE**

It is important for cadets to know the characteristics of the planets in our solar system as space exploration continues to develop. The exploration of the solar system is long term and will span many generations. Cadets who are familiar with the solar system may be able to contribute to this exploration.



Distribute to each cadet a copy of the Planet Specifications Sheet located at Attachment A to be completed as the information is presented during the lesson.

### Teaching Point 1

**Discuss the planet Mercury.**

Time: 5 min

Method: Interactive Lecture

## MERCURY

The planet Mercury, named for the Roman messenger god, is the closest planet to the sun. It is the smallest planet and a cratered wasteland. Since it is so close to the sun it means the planet is completely at the mercy of solar radiation, solar flares, and other solar weather phenomena. The planet is also battered by the many asteroids that float through space. The sun's gravitational pull means that these free floating bodies of rock accelerate towards the sun. Depending on Mercury's position in orbit, these asteroids may impact its surface. There are craters on Mercury that are 600 km wide. Our knowledge of this planet is still incomplete. Only one man-made satellite has ever passed by Mercury, and it was able to collect information about only a small portion of the planet's surface.

### Mean Distance From the Sun

Mercury is the closest planet to the sun. The range varies from 46 million to 69.8 million km. The mean distance is 57.9 million km.

### Size

Mercury's diameter is a mere 4 879 km. The planet's diameter is only 0.383 times that of Earth.

### Mass

Mercury is the smallest planet in our solar system. Its mass is 0.0553 times the mass of Earth.

### Rotation

Despite the quick pace that the planet travels around the sun, Mercury does not rotate around its own axis very quickly. It takes 58.65 days for the planet to rotate around its axis, or two-thirds of a Mercurian year.

### Inclination

The axis of Mercury sits at an angle of 0.01 degrees relative to the sun's axis.

### Orbit Characteristics

Mercury has what is known as an eccentric orbit. This means that the distance the planet is from the sun varies throughout its revolution around the sun. The actual shape that the planet would travel around the sun would be an ellipse. This can be seen in the extreme range in the planet's distance from the sun. Mercury travels around the sun once every 88 days. This means that the Mercurian year is 88 days long. Mercury's synodic period is 115.9 days.



**Synodic period.** The time it takes for a planet to return to a specific spot in the night sky as observed from Earth.

Mercury has an average orbital velocity of 47.9 km / s. This means that the planet travels in its orbit around the sun at an average speed of 47.9 km / s or 172 440 km / h.

### **CONFIRMATION OF TEACHING POINT 1**

The cadets' completion of Mercury's specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

### **Teaching Point 2**

**Discuss the planet Venus.**

Time: 5 min

Method: Interactive Lecture

### **VENUS**

Travelling from the sun past Mercury, the next planet is Venus. Named for the Roman goddess of love and beauty, Venus is constantly cloaked in cloud. This permanent cover means that scientists know very little about the surface of the planet. Observed from Earth, Venus is the brightest planet in the night sky. The Space Age has greatly enhanced our understanding of this planet. Prior to the 1960s, it was thought that Venus was an oceanic planet equivalent in vegetation to Earth during pre-historic periods. Since the 1960s, several satellites have been sent to Venus or on a path near Venus. These satellites have included Mariner 2 and 10, and the Russian Venera 7, 9, and 13 landings.

#### **Mean Distance From the Sun**

Venus is the second closest planet to the sun at a mean distance of 108.2 million km. The distance can range from 107.5 million to 108.9 million km.

#### **Size**

Venus is very similar in size to Earth. Many scientists refer to Venus and Earth as near-twins. The diameter of the planet at the equator is 12 104 km, approximately 0.949 times that of Earth.

#### **Mass**

The mass of Venus is approximately 0.815 times the mass of Earth.

#### **Rotation**

Venus is unique in that it is the only planet in our solar system which rotates east to west, or clockwise. All other planets, including Earth, rotate west to east or counter-clockwise. It takes just over 243 days for Venus to rotate around its axis. It should be noted that this is longer than the Venusian year.

#### **Inclination**

The axis of Venus sits at an angle of 177.4 degrees. This means that the planets north pole is actually at the bottom of the planet.

#### **Orbit Characteristics**

Venus' orbit around the sun is almost perfectly circular which explains the small range of distance from the sun. It takes 224.7 days for Venus to complete one revolution around the sun. This means that one year on Venus is 224.7 days long. Venus' synodic period is 583.92 days, meaning that the planet will return to the same point in the Earth's sky almost every two years. Venus has an orbital velocity of 35.02 km / s or 126 072 km / h.

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## CONFIRMATION OF TEACHING POINT 2

The cadets' completion of Venus' specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

---

### Teaching Point 3

**Discuss the planet Earth.**

Time: 10 min

Method: Interactive Lecture

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## EARTH

The Earth is the third planet from the sun and is the only planet known to support life. The Earth's atmosphere is composed mainly of nitrogen and oxygen. The temperatures are moderate, due to the ozone layer found in our atmosphere. There is water on Earth, which in current scientific belief is an absolute requirement for life.

Earth has one naturally occurring satellite, Luna. Usually, Luna is simply referred to as the moon. The moon has a profound effect on Earth. Not only is it a constant feature in the night sky, but being the brightest object means that it can provide light on a clear night. Being so close to the Earth (384 000 km) and with a diameter of 3 475 km, the moon also has a gravitational effect on our planet. This effect is most apparent in the tidal patterns of our oceans.

### Distance From the Sun

The Earth's average distance from the sun is 149.6 million km. Due to the orbit this can range from 147.1 million to 152.1 million km.

### Size

Since humans have studied the Earth in depth, we tend to base all of our concepts of planet size relative to the Earth. Earth is therefore the standard by which we measure the size of other planets. Earth's diameter is 12 756 km at the equator.

### Mass

Earth's mass is  $5.97 \times 10^{21}$  tonnes. Earth's ratio values for both size and mass are one, since we use the Earth as the standard for measurement.

### Rotation

The Earth rotates west to east around its axis. It takes 23h 56m 04s for the Earth to complete one rotation. This means that the standard Earth day is approximately 24 hours in length.

### Inclination

Earth's axis is tilted at an angle of 23.5 degrees.

### Orbit Characteristics

The Earth's orbit is very circular as seen by the small range in distance from the sun. It takes 365.2 days for the Earth to revolve once around the sun. As such, our standard year is 365 days in length with a leap year every four years to take into account the 0.2 days. The Earth has an orbital velocity of 29.8 km / s or 107 280 km / h.



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**CONFIRMATION OF TEACHING POINT 3**

The cadets' completion of Earth's specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

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**Teaching Point 4****Discuss the planet Mars.**

Time: 5 min

Method: Interactive Lecture

---

**MARS**

Mars is the fourth planet from the sun. Named after the Roman god of war due to its red colour, there are many legends that claim this planet was bright in the sky on the eve of many great victories. Mars has taken a central place in many of today's space programs. At its closest, Mars is 59 million km away from Earth, making it the second-closest planet after Venus. During the space race of the 1960s, the goal was to be the first to set foot on the moon. Now, there is a collaborative effort by many international space agencies to send a manned mission to Mars. The planet itself is currently deemed uninhabitable without the use of artificial environment resources. There have been many probes sent to Mars in recent years to assess the natural environment and evaluate what equipment would be needed in order to sustain human life on the planet.

**Mean Distance From the Sun**

Mars is nearly twice the Earth's distance from the sun. The mean distance the planet is from the sun is 227.9 million km. This ranges from 206.6 million to 249.2 million km depending on its position in its orbit around the sun.

**Size**

The diameter of Mars at the equator is 6 792 km, which is 0.532 times that of Earth.

**Mass**

The mass of Mars is 0.107 times that of Earth.

**Rotation**

Like Earth, Mars' rotation is west to east and takes 24h 39m 35s. In other words, a standard Earth day is very close in duration to a Martian day.

**Inclination**

The axis of Mars is also very similar to Earth's. The axis of Mars is tilted at an angle of 25.2 degrees.

**Orbit Characteristics**

The orbit of Mars is eccentric, as shown by the large range in distance from the sun. Mars will revolve around the sun once every 687 days (a little less than two years). Mars has an orbital velocity of 24.1 km / s or 86 760 km / h.

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**CONFIRMATION OF TEACHING POINT 4**

The cadets' completion of Mars' specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

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**Teaching Point 5****Discuss the planet Jupiter.**

Time: 10 min

Method: Interactive Lecture

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**JUPITER**

After passing through the ring of the asteroid belt, the next planet past Mars is Jupiter, the innermost gas giant planet. Named after the leader of the Roman gods (Zeus to the Greeks), Jupiter is the largest planet in our solar system. Despite its distance from the Earth, the only planets that can outshine it in the night sky are Earth's neighbours, Venus and Mars.

Jupiter has 63 known natural satellites. Of these, 47 are less than 10 km in diameter, and only 4 are large enough to be considered moons. These are identified as Galilean moons and include:

- Io is in orbit 421 600 km from the centre of Jupiter and takes 1.7 days to orbit the planet. The dimensions of Io are not exactly spherical, measuring 3 660 km by 3 637 km by 3 631 km.
- Europa is in orbit 670 900 km from the centre of Jupiter. It takes 3.5 days for the moon to orbit the planet once. Europa is 3 130 km in diameter.
- Ganymede is in orbit 1 070 000 km from the centre of Jupiter and it takes 7.2 days to complete one full orbit of the planet. Ganymede is 5 268 km in diameter.
- Callisto is in orbit 1 880 000 km from the centre of Jupiter and orbits once every 16.7 days. Callisto is 4 806 km in diameter.

**Mean Distance From the Sun**

Though Jupiter is the fifth planet in our solar system, the separation provided by the asteroid belt means that Jupiter is a great distance from the sun. The mean distance of Jupiter from the sun is 778.4 million km. Due to its orbit this distance can range from 740.5 million to 816.6 million km.

**Size**

The diameter of Jupiter at its equator is 142 984 km, 11.21 times that of Earth. Due to the rotation of Jupiter, there is a significant difference between the diameter at the equator and the diameter at the poles. The polar diameter is 133 700 km, almost 10 000 km less than the equatorial diameter. By comparison, the difference in diameter between the Earth's equator and poles is a mere 42 km.

**Mass**

Jupiter's mass is 317.8 times the mass of Earth.

**Rotation**

Jupiter rotates at an immense speed which causes the equator to bulge out. This is the reason for the large difference between the equatorial and polar diameters. One day on Jupiter is only 9h 55m 30s.

**Inclination**

Jupiter's axis is only 3.1 degrees from the perpendicular, meaning that Jupiter is almost straight up and down.

**Orbit Characteristics**

Jupiter has a slightly eccentric orbit. Due to its distance from the sun, it takes the planet 4 331 days (11.86 years) to revolve around the sun. The orbital velocity of Jupiter is 13.1 km / s or 47 160 km / h. Jupiter's synodic period is 398.9 days.

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**CONFIRMATION OF TEACHING POINT 5**

The cadets' completion of Jupiter's specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

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**Teaching Point 6****Discuss the planet Saturn.**

Time: 5 min

Method: Interactive Lecture

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**SATURN**

Saturn is a very distinct planet in our solar system. It is the second of the gas giants from the sun, the sixth planet in the system. Named after the Roman god of time because of the length of time it takes for the planet to cross the night sky, Saturn is said to be the most beautiful object in the sky when viewed through a telescope.

**Mean Distance From the Sun**

Saturn is more remote than Jupiter. Orbiting at a mean distance of 1 433.5 million km, Saturn is almost twice as far from the sun as Jupiter.

**Size**

Saturn's equatorial diameter is 120 536 km, which is more than nine times that of the Earth. Saturn is the second largest planet in the solar system.

**Mass**

Saturn's mass is 95.2 times the mass of Earth.

**Rotation**

Saturn rotates on its axis once every 10h 13m 59s. Like Jupiter, the speed at which this occurs causes a slight bulging at the equator, causing the large distortion between the equatorial diameter and the polar diameter.

**Inclination**

The axis of Saturn tilts at an angle of 26.7 degrees.

**Orbit Characteristics**

Saturn has a slightly eccentric orbital path. It travels around the sun in 10 747 days or 29.43 years. Saturn's synodic period is 378.1 days. The orbital velocity of Saturn is 9.7 km / s or 34 920 km / h.

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**CONFIRMATION OF TEACHING POINT 6**

The cadets' completion of Saturn's specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

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**Teaching Point 7****Discuss the planet Uranus.**

Time: 5 min

Method: Interactive Lecture

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**URANUS**

Uranus is a very distinct planet which shares some of the characteristics of Saturn. Most prominent of these are the rings which orbit the planet, but even here there is uniqueness. Uranus is barely visible to the naked eye and the study of Uranus actually led to the discovery of the next planet in the solar system. The planet is named after the mythological father of Saturn.

**Mean Distance From the Sun**

Uranus is the second-furthest planet from the sun. The mean distance is 2 872.5 million km with a maximum of 3 003.6 million km and a minimum of 2 741.3 million km. Compared to Saturn, Uranus is twice as far from the sun and four times as far as Jupiter.

**Size**

Uranus is just over one third the size of Jupiter, but is still the third largest planet in the solar system. It has an equatorial diameter of 51 118 km, which is 4.01 times that of Earth.

**Mass**

Uranus' mass is 14.5 times that of Earth.

**Rotation**

Uranus rotates around its axis once every 17h 14m.

**Inclination**

The axis of Uranus tilts at an angle of 97.8 degrees. This means that it is technically on its side and the rings of Uranus look like they are vertical compared to Saturn's rings. Also, the satellites orbit Uranus on a vertical plane instead of a horizontal plane like the other planets.

**Orbit Characteristics**

Uranus has an irregular orbit. There is a point in the orbit where Uranus, as viewed from Earth, performs two 180-degree turns. This would look like a giant Z in the orbital path. It takes Uranus 83.76 years to orbit the sun once. Its mean orbit velocity is 24 607 km / h. The synodic period of Uranus is 369.7 days.

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**CONFIRMATION OF TEACHING POINT 7**

The cadets' completion of Uranus' specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

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**Teaching Point 8****Discuss the planet Neptune.**

Time: 5 min

Method: Interactive Lecture

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**NEPTUNE**

Named after the Roman god of the sea, Neptune was found as a result of scientific study of Uranus. Almost all of our knowledge of Neptune comes from one spacecraft, Voyager 2, which flew past the planet in 1989. The

atmosphere is made up predominantly of hydrogen, helium and methane. The planet is a very windy place, with equatorial winds in excess of 450 m / s or 1 620 km / h.

### **Mean Distance From the Sun**

Neptune is approximately half again as far as Uranus from the sun. Orbiting at a mean distance of 4 495.1 million km, it is 20 times as far as Mars. Neptune is the last planet in the solar system, keeping in mind that Pluto has been down-graded to a dwarf-planet.

### **Size**

Neptune is nearly identical in diameter to Uranus at 49 528 km, 3.88 times the diameter of the Earth.

### **Mass**

Neptune's mass is more than 18 percent greater than Uranus' and 17.1 times the mass of the Earth.

### **Rotation**

It takes Neptune 16h 7m to rotate once around its axis. This is the third fastest rotation of all of the planets.

### **Inclination**

The tilt of Neptune's axis is 28.3 degrees, slightly more than Earth's.

### **Orbit Characteristics**

Neptune's orbit is almost perfectly circular. It takes Neptune 163.7 years to orbit the sun, almost twice as long as Uranus. Its mean orbit velocity is 19 720 km / h. Neptune's synodic period is 367.5 days.

## **CONFIRMATION OF TEACHING POINT 8**

The cadets' completion of Neptune's specification box on the Planet Specification Sheet will serve as the confirmation of this TP.

## **END OF LESSON CONFIRMATION**

Show the cadets the slides of Attachment B and have them correct their own notes on the *Planet Specifications Sheet* located at Attachment A, which they completed during the lesson.

## **CONCLUSION**

### **HOMEWORK / READING / PRACTICE**

Nil.

### **METHOD OF EVALUATION**

Nil.

### **CLOSING STATEMENT**

The planets are more than just individual bodies floating in space. They are part of a large system and in some cases they are the centre of their own sub-system. Understanding the scale of this system is very important to understanding space exploration. With the mission to Mars moving in to the forefront of space news, we need to realize that this is not a small project, but one that could take years because of the distance and equipment

required. In addition, understanding the scale of the solar system and the scale location of the nearest star gives us a taste of the vastness of the universe and the importance of astronomy in our lives.

### **INSTRUCTOR NOTES / REMARKS**

Planetary data is provided in detail at <http://solarsystem.nasa.gov/planets/index.cfm>

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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## PLANET SPECIFICATIONS SHEET

### Mercury

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

### Venus

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

### Earth

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

### Mars

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

**Jupiter**

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

**Saturn**

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

**Uranus**

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

**Neptune**

Distance from the sun: \_\_\_\_\_ million km. Size: \_\_\_\_\_ km.

Mass \_\_\_\_\_ Earth Mass

Axis - Time of rotation: \_\_\_\_\_ Axis - Inclination: \_\_\_\_\_ degrees

Orbit: \_\_\_\_\_ days Orbit speed \_\_\_\_\_ km / h.

## PLANET SPECIFICATIONS ANSWER KEY

### Mercury

Distance from the sun: 57.9 million km      Size: 4 879 km

Mass 0.0553 Earth masses

Axis - Time of rotation: 58.65 d      Axis - Inclination: 0.01 degrees

Orbit: 88 days      Orbit speed 172 440 km / h.

### Venus

Distance from the sun: 108.2 million km      Size: 12 104 km

Mass 0.815 Earth masses

Axis - Time of rotation: 243 d      Axis - Inclination: 177.4 degrees

Orbit: 224.7 days      Orbit speed 126 072 km / h.

### Earth

Distance from the sun: 149.6 million km      Size: 12 756 km

Mass: 1 Earth masses.

Axis - Time of rotation: 23h 56m 4s      Axis - Inclination: 23.5 degrees

Orbit: 365.2 days      Orbit speed 107 280 km / h.

### Mars

Distance from the sun: 227.9 million km      Size: 6 792 km

Mass: 0.107 Earth-masses

Axis - Time of rotation: 24h 37m 23s      Axis - Inclination: 25.2 degrees

Orbit: 687 days      Orbit speed 86 760 km / h.

### **Jupiter**

Distance from the sun: 778.6 million km      Size: 143 984 km

Mass 317.8 Earth-masses

Axis - Time of rotation: 9h 55m 30s    Axis - Inclination: 3.1 degrees

Orbit: 11.86 years                      Orbit speed 47 160 km / h.

### **Saturn**

Distance from the sun: 1 433.5 million km      Size: 120 536 km

Mass 95.2 Earth masses

Axis - Time of rotation: 10h 13m 59s    Axis - Inclination: 26.7 degrees

Orbit: 29.43 years                      Orbit speed 34 920 km / h.

### **Uranus**

Distance from the sun: 2 872.5 million km      Size: 51 118 km

Mass 14.5 Earth masses

Axis - Time of rotation: 17h 14m    Axis - Inclination: 97.8 degrees

Orbit: 83.76 years                      Orbit speed 24 607 km / h.

### **Neptune**

Distance from the sun: 4 495.1 million km      Size: 49 528 km

Mass 17.1 Earth masses

Axis - Time of rotation: 16h 7m    Axis - Inclination: 28.3 degrees

Orbit: 163.7 years                      Orbit speed 19 720 km / h.



**ROYAL CANADIAN AIR CADETS**  
**PROFICIENCY LEVEL FOUR**  
**INSTRUCTIONAL GUIDE**



**SECTION 6**

**EO C440.04 – APPLY THE MATERIAL SCIENCE OF TRUSSES**

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Total Time: 90 min

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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of Attachments A and B.

For each pair of cadets, construct one suspended container mount (SCM), described at Attachment C, for use in TP 3.

Photocopy the handouts at Attachment C for each pair of cadets.

Obtain one lightweight container for suspension from the SCM, such as a sandwich bag and wire, for incrementally adding marbles when testing the strength of trusses.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for TP 1 to generate interest in the material science of trusses and summarize the teaching point.

A practical activity was chosen for TPs 2 and 3 as it is an interactive way to allow the cadets to design and test a truss in a safe and controlled environment.

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**INTRODUCTION**

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**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall have applied the material science of trusses by constructing and testing a truss.

**IMPORTANCE**

It is important for cadets to apply the material science of trusses as they are a common aerospace structural component due to their light weight and strength.

**Teaching Point 1****Explain the material science of trusses.**

Time: 15 min

Method: Interactive Lecture

Successful structures must withstand the loads and forces that act upon them. When a load (external force), such as gravity or a person's weight, is applied to a structure, forces are produced within the structure (internal forces) to resist the load. Provided the internal forces equal the external forces, the structure will retain its integrity. When imbalances of internal and external forces occur, a structure may suffer a catastrophic failure.

**TYPES OF LOADS**

The two most significant forces on structures are compression and tension. In order for a structure to resist static and dynamic loads, it must be engineered appropriately.

**Static loads.** Loads that remain constant. The weight of the materials from which a structure is made exerts an internal static force on the structure. Gravity is a static load.

**Dynamic loads.** Loads that exert constantly changing forces upon a structure. A car crossing a bridge exerts external dynamic forces on the bridge that must be counteracted by internal forces within the bridge. The structure of the International Space Station (ISS) must resist bending and twisting when it is moved by docking spacecraft or the Canadarm 2.

**PROPERTIES OF MATERIALS**

**Elastic.** Material is considered elastic when it is capable of sustaining deformation without permanent loss of size or shape. Almost all materials have some elastic properties. Glasses and crystals tend to be the least elastic solids whereas organic substances such as rubber and wood tend to show considerable elasticity. Some metals, especially some alloys of iron, can be very elastic.



Show the cadets Figure A-1 located at Attachment A.

**Plastic.** If a substance is compressed or stretched beyond a certain limit (called its elastic limit) it begins to exhibit plastic-like properties and it will become permanently deformed. Once a material is stretched or compressed beyond its elastic limit it is said to enter a plastic phase.



Show the cadets Figure A-2 located at Attachment A.



The word "plastic" in this case refers to the physical properties of the material, NOT the substance(s) we call "plastic"—which is the common term for a wide range of synthetic or semisynthetic organic solid materials used in the manufacture of products.

Materials that have plasticity may exhibit either of the following:

- **Malleability.** The material is capable of undergoing plastic deformation without rupture, especially metals.
- **Ductility.** The ability of a material to be plastically deformed by elongation without fracture.



All materials have some degree of elasticity and plasticity, but when a material fractures easily it is said to be brittle. A material is brittle if it is liable to fracture when subjected to stress. It has little tendency to deform (or strain) before fracture. This fracture absorbs relatively little energy, even in materials of high strength, and usually makes a snapping sound.



Show the cadets Figure A-3 located at Attachment A.

## APPLIED FORCE

The effects of applying force can be illustrated on a cube of material. The side view of the cube is shown as the shape of a square. When no external forces are present the cube is considered in a neutral state.



Show the cadets Figure A-4 located at Attachment A.

When external forces are applied while the cube remains stationary (eg, the cube does not accelerate under the application of the applied force) it is said to be in a non-neutral condition of which there are several possibilities.

**Compression.** If the cube is supported from below so that it is unable to move, while a downward force is applied on the top of the cube, the cube is said to be in a state of compression. In this state, the cube tends to deform, becoming slightly shorter and wider.



Show the cadets Figure A-5 located at Attachment A.

If the material from which the cube is made is elastic, it will return to its original shape when the compressing force is removed. If the material from which the cube is made is plastic and non-elastic, it will undergo permanent deformation. When the material is long and thin, compressive forces can cause buckling, where the material fails due to elastic instability.



Show the cadets Figure A-6 located at Attachment A.

**Tension.** If the cube is securely fastened at its lower surface (perhaps glued to the surface upon which it is sitting) and an upward force is applied to its upper surface, the cube is said to be in a state of tension. The effect is to make the cube stretch upward while contracting inward around its sides.



Show the cadets Figure A-7 located at Attachment A.

If the material from which the cube is made is elastic, it will return to its original shape when the tensile (stretching) force is removed. If the material from which the cube is made is plastic and non-elastic, it will undergo permanent deformation.



Show the cadets Figures A-8 and A-9 located at Attachment A.

**Shear.** If the cube deforms as illustrated in Figure A-8, it is called shear. If the material from which the cube is made is elastic, it will return to its original shape when the shearing force is removed. If the material from which the cube is made is plastic and non-elastic it will undergo permanent deformation.

**Shear stress.** When forces are applied in such a way that the different parts of the cube try to slide with respect to one another, the effect is also called shearing. If parts of the cube try to slide, it is called shear stress.



Show the cadets Figure A-10 located at Attachment A.

**Torsion.** Torsion is the twisting of an object due to an applied torque. If the top of the cube is rotated while the bottom is fixed, the cube will twist.

---

## CONFIRMATION OF TEACHING POINT 1

### QUESTIONS:

- Q1. What is a static load on a structure?
- Q2. What happens to an object under tension?
- Q3. What will torque do to an object?

### ANTICIPATED ANSWERS:

- A1. A load that remains constant.
- A2. The object will stretch while contracting inward around its sides.
- A3. It will twist the object.

**Teaching Point 2****Have the cadets, in pairs, design a truss.**

Time: 15 min

Method: Practical Activity

**Truss.** Any of various structural frames based on the geometric rigidity of the triangle and composed of straight members connected at joints referred to as nodes, subject only to longitudinal compression, tension, or both. At a minimum, a truss will have three members and three nodes. Trusses offer the most strength using the least weight: an important factor in spacecraft design.



Show the cadets Figures B-1 and B-2 located at Attachment B.

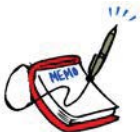
A planar truss is one where all the members and nodes lie within a two dimensional plane. A space truss has members and nodes extending into three dimensions.

When designing a truss, consider the following:

- effect of tension versus compression on member sizes and lengths;
- approaches to preventing potential buckling failure modes;
- potential for stress reversal; and
- overall lateral stability (lateral-torsional buckling).

The first step in constructing a truss is to understand what the truss will be used for and what forces will be placed on the truss. When the parameters have been established, putting the design on paper or using computer aided design (CAD) software will save time and material.

The truss will be tested by applying weight at its centre via the suspended container mount. Weight will be added until the truss fails. This test will demonstrate one aspect of truss design as it is an application of only one force on the truss.



Distribute the handout of Attachment C to each cadet.

**ACTIVITY**

Time: 10 min

**OBJECTIVE**

The objective of this activity is to have the cadets, in pairs, design a truss to be constructed out of uncooked spaghetti and hot glue.

## RESOURCES

Material required by each pair of cadets:

- Photocopy of Attachment C,
- One legal size graph paper pad,
- Two mechanical pencils,
- One eraser,
- One 30-cm ruler,
- One plastic protractor, and
- 24 unbroken strands of uncooked spaghetti.

## ACTIVITY LAYOUT

Nil.

## ACTIVITY INSTRUCTIONS

1. Distribute the required material to each pair of cadets.
2. Have each pair of cadets design a truss.



The truss will be constructed out of uncooked spaghetti and hot glue. When designing the truss keep these factors in mind:

- The truss will be assessed on its strength to weight ratio. A light truss that supports the same weight as a heavy truss will be assessed a higher value.
- The buckling point of a member is related to its length. The longer the member, the greater the chance of buckling. Shorter pieces of spaghetti are better in compression. Long strands of spaghetti are stronger in tension than they are in compression.
- The suspended container mount consists of a block of plywood with a screw eye in its centre and is used to hold the suspended container of marbles. Be precise with the suspended container mount position and dimensions. All the weight that the truss will carry is supported by this mount.
- Truss members can be made up of more than one strand of spaghetti.
- The truss will be supported on each end by an abutment, represented by tables set 45 cm apart.

## SAFETY

Nil.

---

## CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**Teaching Point 3****Have the cadets, in pairs, construct and test a truss.**

Time: 50 min

Method: Practical Activity

---



The truss testing is a competition between the pairs of cadets and not an assessment.

The truss construction should follow the design as closely as possible. Points will be lost for trusses that do not follow the original design or that waste material. Points will be gained for construction technique and neatness.

The suspended container will be filled with marbles. When the truss fails, the amount of marbles in the suspended container will be counted and divided by the weight of the bridge. This ratio will be used in the total score.

Neatness counts!

---

**ACTIVITY**

Time: 45 min

**OBJECTIVE**

The objective of this activity is to have the cadets, in pairs, construct and test a truss.

**RESOURCES**

Material required by each pair of cadets:

- Suspended container mount,
- Glue gun,
- Hot glue sticks,
- Hobby knife, and
- Uncooked spaghetti.

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Distribute the materials to each pair of cadets.
2. Have the cadets, within 35 minutes, use their truss designs from TP 2 to construct the truss.
3. Have the cadets test their trusses for the remaining 10 minutes.
4. Use the scoring sheet at Attachment C to record the test results.



Hot glue is hot enough to cook the spaghetti, which will result in a weakened node or member. Apply only a small amount of heat and glue to connect the members.

---

**SAFETY**

Use caution with the hot glue gun and glue. The glue and gun can reach 120–195 degrees Celcius. This is hot enough to burn flesh.

---

**CONFIRMATION OF TEACHING POINT 3**

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**END OF LESSON CONFIRMATION**

This lesson should be taught in three consecutive periods.

The cadets' construction of a truss will serve as the confirmation of this lesson.

---

**CONCLUSION**

---

**HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

Although the International Space Station is made largely of aluminum instead of spaghetti, it is an application of the material science of trusses, using the same principles as any truss.

**INSTRUCTOR NOTES / REMARKS**

Cadets who qualified Advanced Aerospace may assist with this instruction.

---

**REFERENCES**

C3-331 McMaster University YES I Can! Science Team. (2009). *How forces act on structures*. Retrieved February 19, 2009, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

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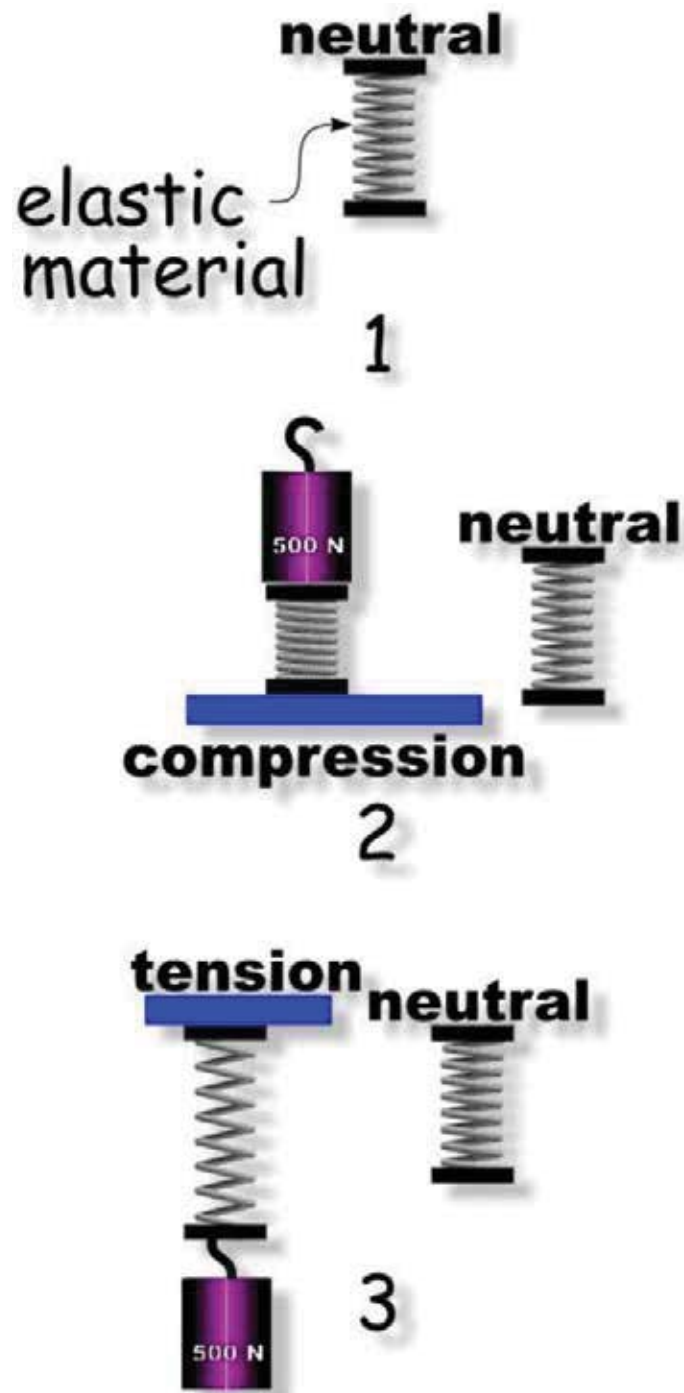


Figure A-1 Elastic Material

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

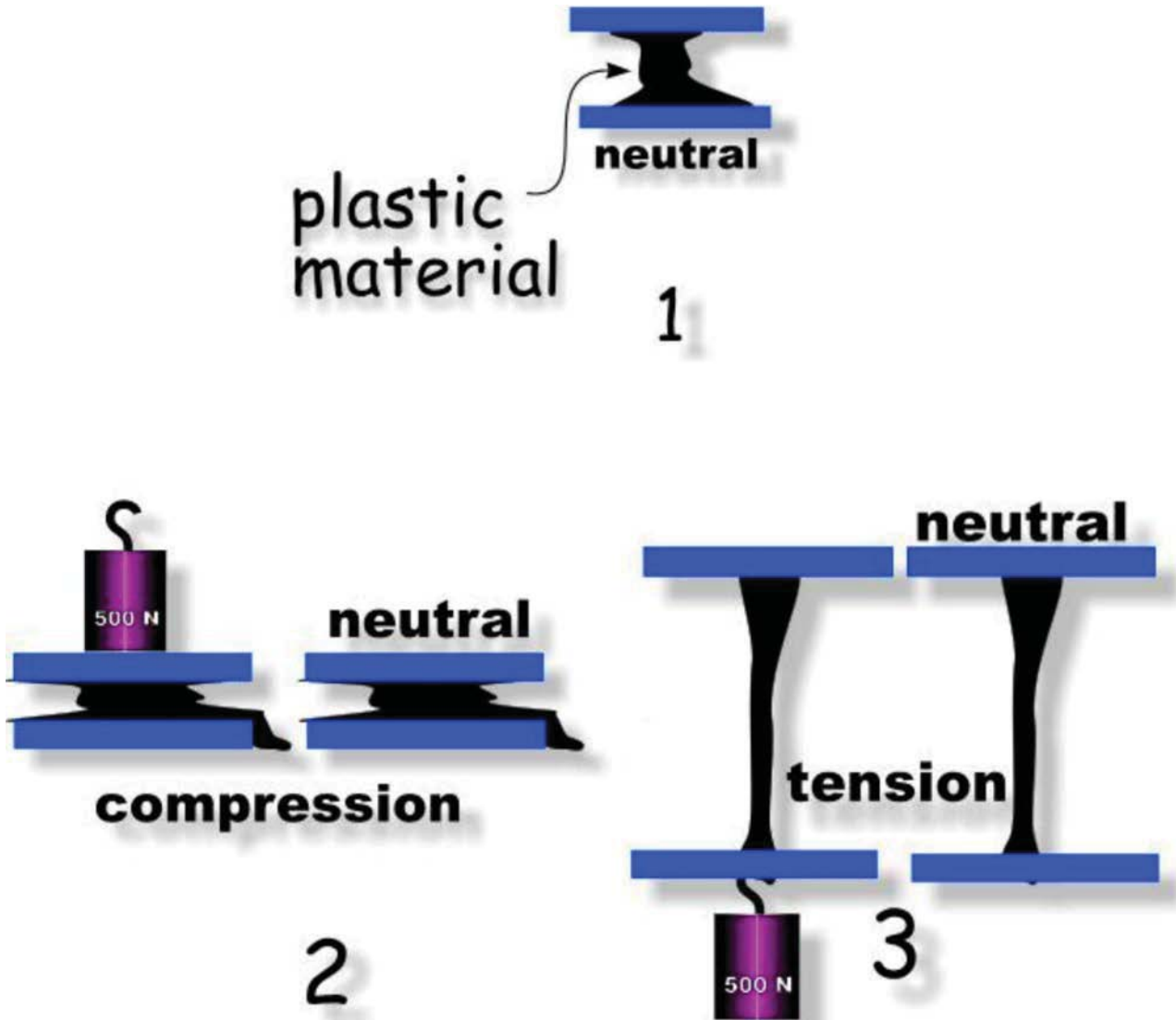


Figure A-2 Plastic Material

Note. From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

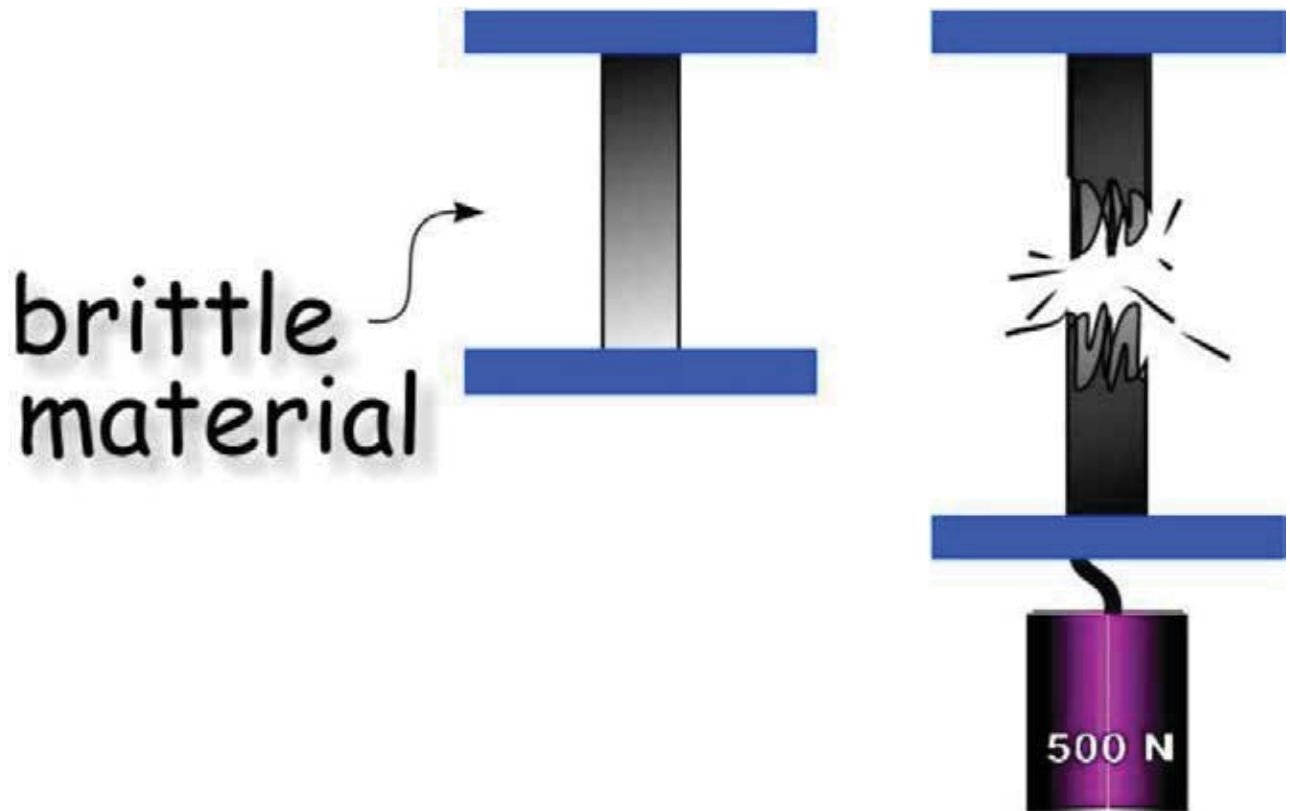


Figure A-3 Brittle Material

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

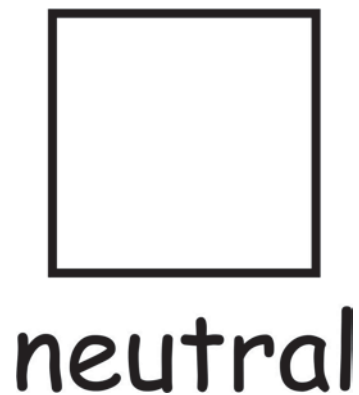


Figure A-4 Cube at Rest

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

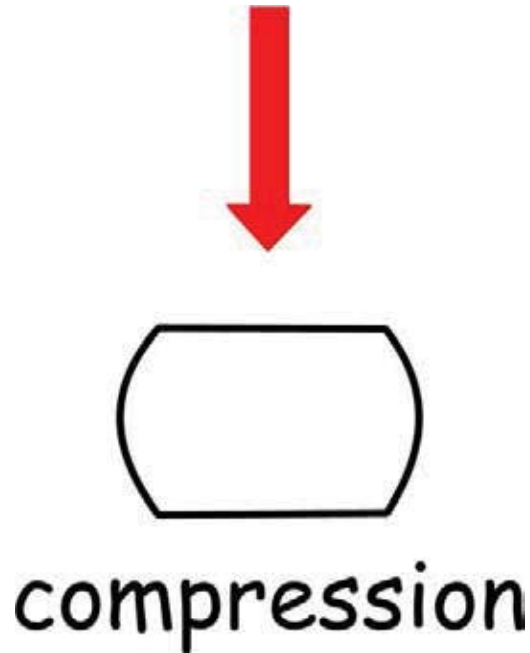


Figure A-5 Cube in Compression

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

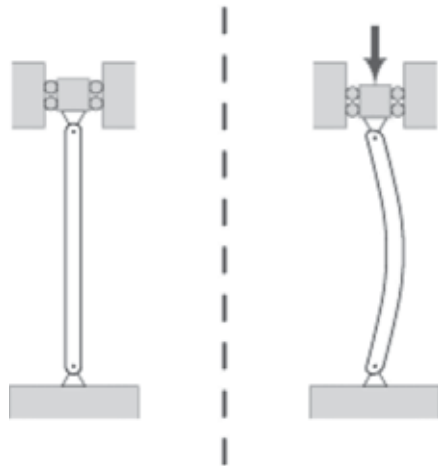


Figure A-6 Compression Causing Buckling

*Note.* From "Buckling", 2008. Retrieved November 25, 2008, from <http://en.wikipedia.org/wiki/Buckling>

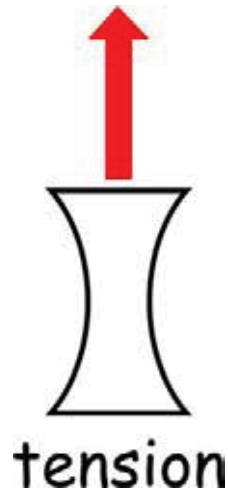


Figure A-7 Cube in Tension

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>

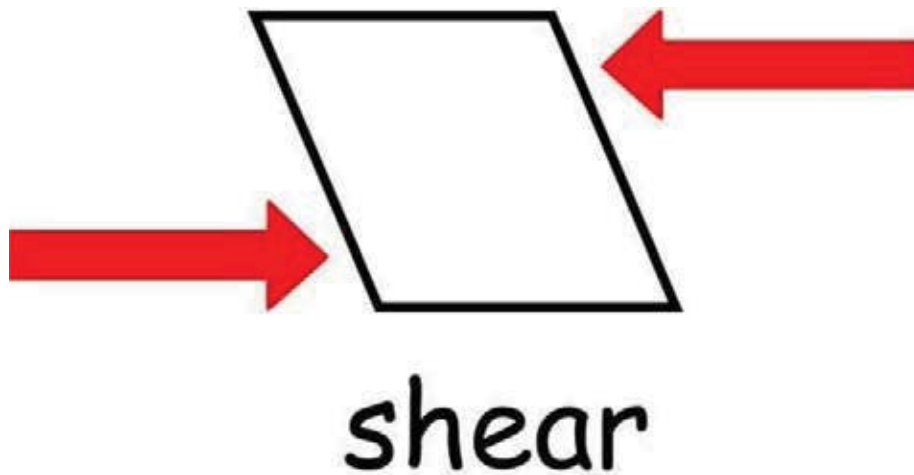
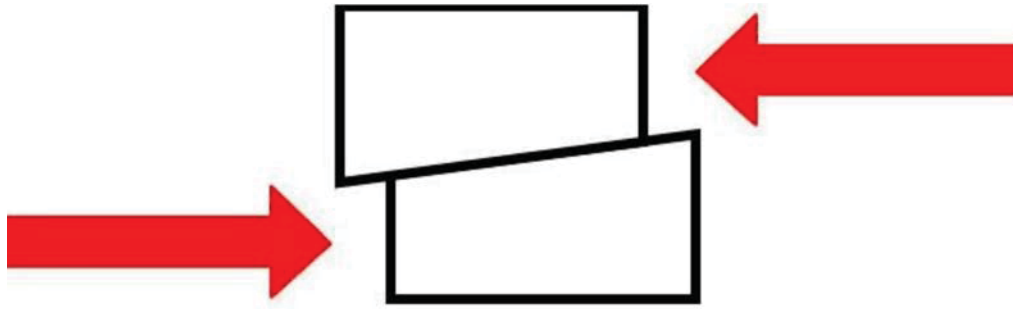


Figure A-8 Cube in Shear

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>



## shear (stress)

Figure A-9 Cube Shear Stress

*Note.* From "Materials, Structures, and Forces", 2008, *Structures in Space*. Retrieved November 20, 2008, from <http://resources.yesican-science.ca/sts115/aboutforces.html>



Figure A-10 Cube in Torsion

*Note.* From "Cube Twist", 2008. Retrieved November 25, 2008, from [http://www.helleronline.com/fgfc1\\_main.php?&color=silver&view=front](http://www.helleronline.com/fgfc1_main.php?&color=silver&view=front)

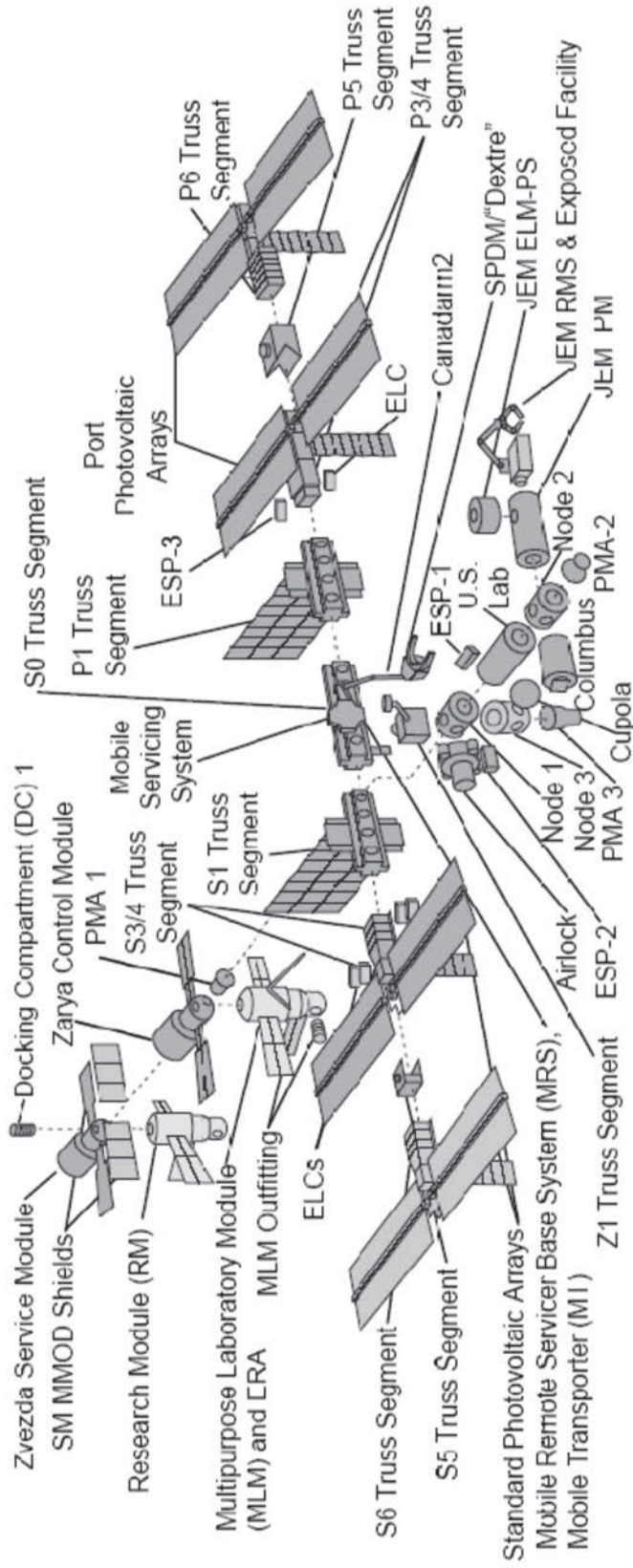


Figure B-1 Exploded View of the ISS Truss Structure

Note. From "Space Exploration", Boeing, 2008, *International Space Station Background*, Boeing. Retrieved February 19, 2009, from [http://www.boeing.com/defense-space/spacestation/docs/ISS\\_overview.pdf](http://www.boeing.com/defense-space/spacestation/docs/ISS_overview.pdf)



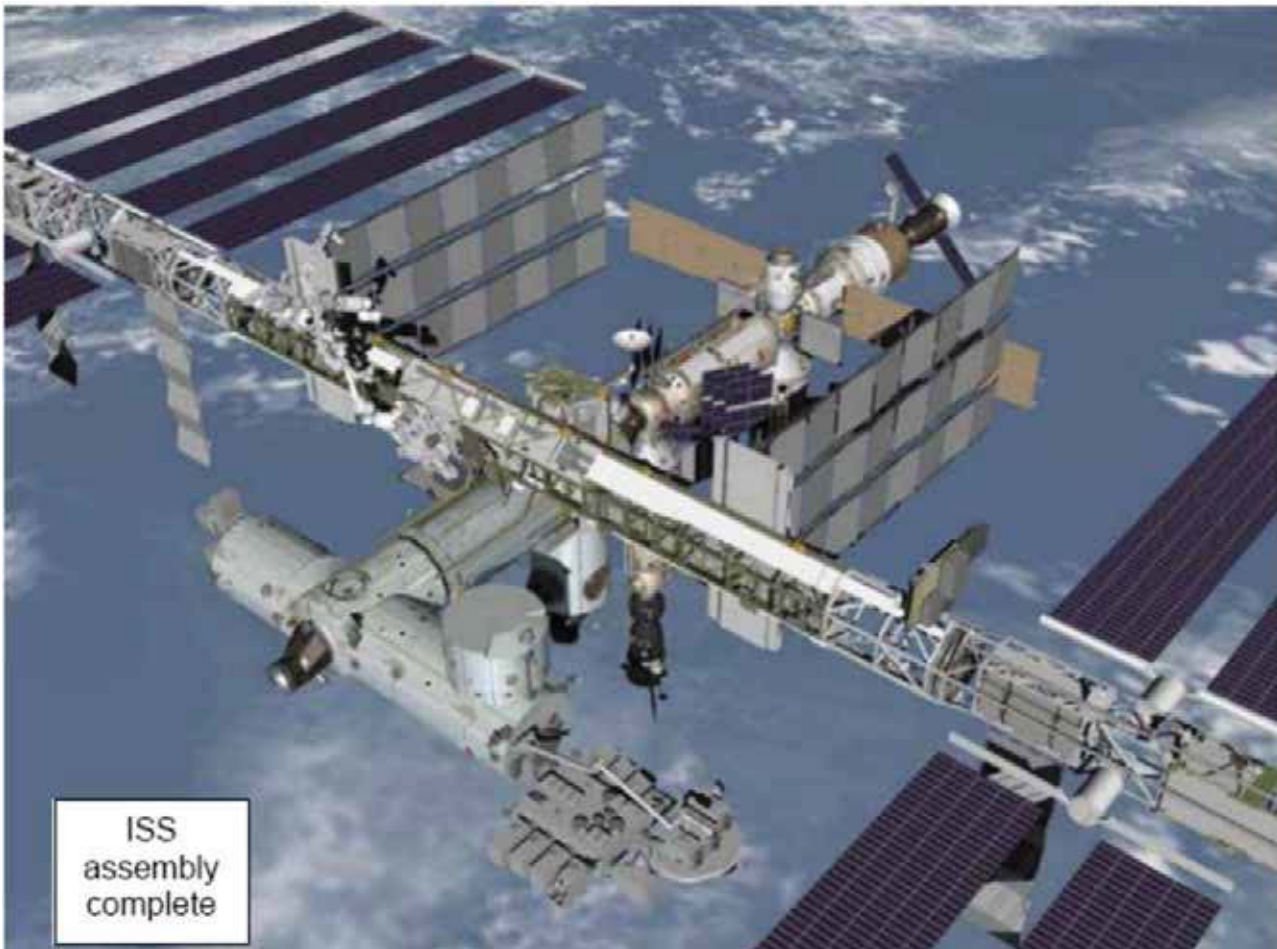


Figure B-2 ISS Truss Structure

Note. From "Space Exploration", Boeing, 2006, *International Space Station Backgrounder*, Boeing. Retrieved November 25, 2008, from [http://www.boeing.com/defense-space/space/spacestation/docs/ISS\\_overview.pdf](http://www.boeing.com/defense-space/space/spacestation/docs/ISS_overview.pdf)

## TRUSS COMPETITION

### Rules and Regulations

Trusses must be constructed of materials provided by the squadron training office. No other materials may be used in the construction of the truss.

Material required by each pair of cadets includes:

- Spaghetti (uncooked, 25 cm long),
- Hot glue gun, and
- Glue sticks.

Parameters for the competition are:

- distance between the abutments: 45 cm,
- length: not less than 47 cm, not greater than 55 cm,
- width: not greater than 10 cm,
- height: not greater than 25 cm,
- no part of the truss will hang below the top of the abutments, and
- time: 40 min.

The provided suspended container mount (SCM) shall be incorporated into the truss. The SCM consists of the following materials:

- 2-cm eye bolt, and
- 8 cm by 8 cm birch plywood square, 4 mm thick.

The following criteria will be used for scoring:

- design,
- quality of construction,
- material use / waste, and
- amount of marbles divided by the weight of the truss.

TRUSS TESTING SCORING SHEET

Cadet Pair	Follows Design <sup>1</sup>	Quality of Construction <sup>2</sup>	Material Use <sup>3</sup>	Length <sup>4</sup>	Width <sup>5</sup>	Height <sup>6</sup>	Amount of Marbles	Weight of Truss	Ratio <sup>7</sup>	Total
	1/0	1/0	1/0	1/0	1/0	1/0				
	1/0	1/0	1/0	1/0	1/0	1/0				
	1/0	1/0	1/0	1/0	1/0	1/0				
	1/0	1/0	1/0	1/0	1/0	1/0				
	1/0	1/0	1/0	1/0	1/0	1/0				

Note:

1. One point for following design; no points for not following design.
2. One point for neat construction; no points for messy construction.
3. One point for minimum waste; no points for wasting material.
4. Subtract one point for over or under 47–55 cm.
5. Subtract one point for over 10 cm.
6. Subtract one point for over 25 cm.
7. Divide the number of marbles in the suspended container by the bridge weight for this ratio.



**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 7**

**EO C440.05 – DESCRIBE ROBOTICS**

Total Time:

30 min

**PREPARATION**

**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of the figures located at Attachments A–C.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for this lesson to give the cadets an overview of robotics and generate interest in the subject.

**INTRODUCTION**

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall have described robotics and shall be expected to identify types of robots.

**IMPORTANCE**

It is important for cadets to be familiar with robot types and various robotic applications because they form an important and growing aspect of the aerospace industry in both manufacturing and operations.

**Teaching Point 1****Describe types of robots.**

Time: 10 min

Method: Interactive Lecture

A robot is defined as a machine that looks and functions like a human being. A robot is also defined as a machine that is capable of carrying out a complex series of tasks automatically. Some organizations provide special definitions of a robot, such as those found at NASA's ROVER Ranch website, which include:

- a machine that looks like a human being and performs various complex acts similar to those of a human being (such as walking or talking);
- a device that automatically performs complicated, often repetitive, tasks; and
- any mechanism guided by automatic controls.



NASA's ROVER Ranch is a place to learn about robotic engineering at <http://prime.jsc.nasa.gov/ROV/>

**AUTONOMOUS SYSTEMS**

Autonomous systems are the physical embodiment of machine intelligence. This means that an autonomous system combines artificial intelligence (AI) with the manipulating abilities of remote-controlled systems.

**REMOTE-CONTROLLED SYSTEMS**

The earliest robots, such as the armoured robot knight created by Leonardo da Vinci in 1495, did not think for themselves. Representing the technology of 1495, Leonardo da Vinci's robot consisted of two independent systems:

- three-degree-of-freedom legs, ankles, knees, and hips; and
- four-degree-of-freedom arms with articulated shoulders, elbows, wrists, and hands.



Examples of Degrees of Freedom (DOF) are:

- tilting forward and backward (pitching);
- turning left and right (yawing);
- tilting side to side (rolling);
- moving up and down (heaving);
- moving left and right (swaying); and
- moving forward and backward (surging).



Show the cadets the slide of Figures A-1 and A-2 located at Attachment A.

The orientation of the arms on Leonardo's robot indicates that it was designed for whole-arm grasping, which means that all the joints moved in unison. A mechanical, analog-programmable controller within the chest provided power and control for the arms.

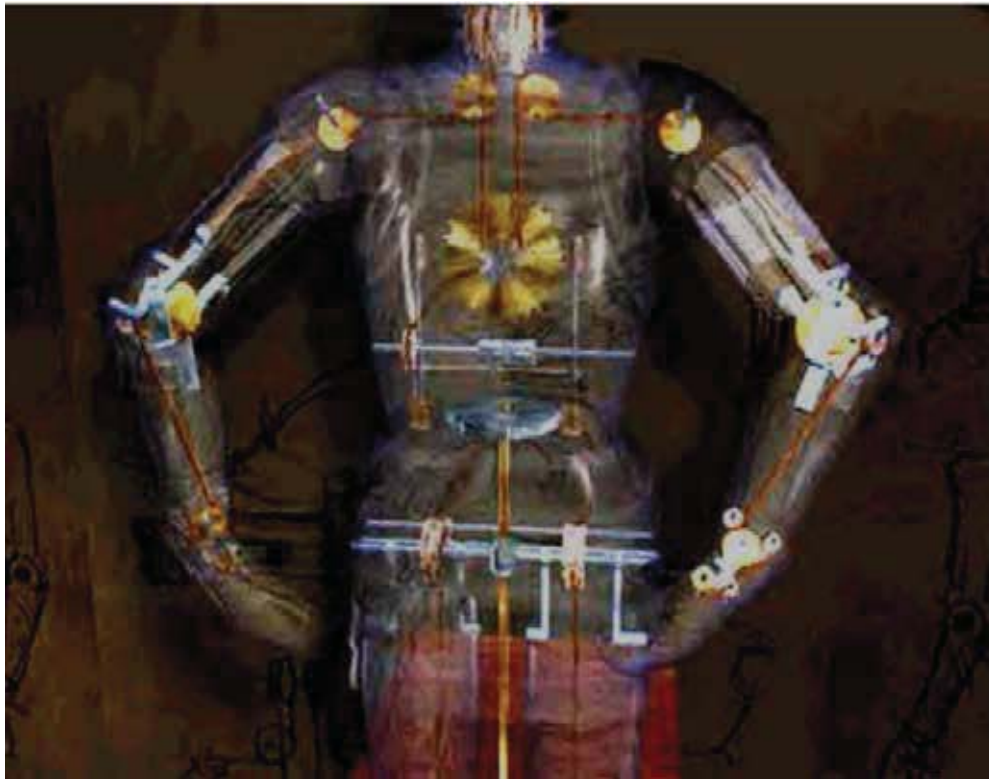


Figure 1 Leonardo's Mechanical Analog-Programmable Controller

*Note.* From "Z-Kat the Digital Surgery Company", by R. Abovitz, 2001, *Leonardo's Robot*, Copyright 2008 by R. Abovitz. Retrieved November 18, 2008, from [http://www.z-kat.com/company/adv\\_research/leonardo.shtml](http://www.z-kat.com/company/adv_research/leonardo.shtml)

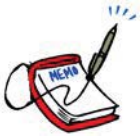
The legs were powered by an external crank arrangement driving the cable, which was connected to key locations in the ankle, knee, and hip. This armoured robot knight was designed to sit up, wave its arms, and move its head via a flexible neck while opening and closing its anatomically correct jaw. It may have made sounds to the accompaniment of automated drums. On the outside, the robot is dressed in a typical German-Italian suit of armour of the late fifteenth century.



Modern robots such as the Canadarm and the Canadarm2 combine the two modes of remote control and autonomy.

### **Canadarm: Shuttle Remote Manipulator System (SRMS)**

The space shuttle's general-purpose computer (GPC) controls the movement of the SRMS. The astronauts use a hand controller, which tells the computer what the astronaut would like the arm to do. Built-in software then studies the astronaut's commands and calculates which joints should move, what direction to move them in, how fast to move them and at what angle to move.



Show the cadets the slide of Figure A-3 located at Attachment A.



Figure A-3 is a scale drawing of the Canadarm.

While the computer is issuing commands to each of the joints, it monitors each joint every 80 milliseconds. Any movements of the astronaut's hand are re-examined and recalculated by the GPC and updated commands are then sent out to each of the joints.

Should a failure occur, the GPC automatically applies the brakes to all joints and notifies the astronaut of a failure condition. The control system also provides a continuous display of joint rates and speeds, which are displayed on monitors located on the flight deck of the shuttle. As with any control system, the GPC can be overridden and the astronaut can operate the joints individually from the flight deck.

---

## CONFIRMATION OF TEACHING POINT 1

### QUESTIONS:

- Q1. What are autonomous systems?
- Q2. What two modes do robots such as the Canadarm and the Canadarm2 combine?
- Q3. What computer controls the SRMS?

### ANTICIPATED ANSWERS:

- A1. Autonomous systems are the physical embodiment of machine intelligence.
- A2. The two modes combined in the Canadarm and the Canadarm2 are remote control and autonomy.
- A3. The space shuttle's general-purpose computer (GPC) controls the movement of the SRMS.

---

## Teaching Point 2

## Describe robotic applications.

Time: 15 min

Method: Interactive Lecture

Robots are especially desirable for certain work functions because, unlike humans, they:

- never get tired;
- can endure physical conditions that are uncomfortable, dangerous or even airless;
- do not get bored by repetition; and
- cannot be distracted from the task at hand.

Early industrial robots that handled radioactive material in atomic labs were called master / slave manipulators. They were connected with mechanical linkages and steel cables. Remote arm manipulators can now be moved by push buttons, switches or joysticks.



Robots sometimes have advanced sensory systems that process information and appear to function as if they have brains. Their "brain" is actually a form of computerized AI, which allows a robot to perceive conditions and decide on a course of action based on these conditions.

A robot may include any of the following components:

- **Effectors.** "Arms", "legs", "hands", "feet".
- **Sensors.** Parts that act like senses, can detect objects or things like heat and light and convert the information into symbols that computers understand.
- **Computer.** The brain that contains instructions called algorithms to control the robot.
- **Equipment.** Includes tools and mechanical fixtures.

Characteristics that make autonomous robots different from regular machinery are that they usually function by themselves, are sensitive to their environment, adapt to variations in the environment or to errors in prior performance, are task-oriented and often have the ability to try different methods to accomplish a task.

## INDUSTRIAL FABRICATION

Typical industrial robots do jobs that are difficult, dangerous or dull. They lift heavy objects, paint, handle chemicals, and perform assembly work. They perform the same job hour after hour, day after day with precision. They do not get tired and they do not make errors associated with fatigue and are ideally suited to performing repetitive tasks.

The major categories of industrial robots, differentiated by mechanical structure are:

- **Cartesian / Gantry robot.** Used for pick and place work, application of sealant, assembly operations, handling machine tools and arc welding. It is a robot whose arm has three joints and whose axes are coincident with Cartesian coordinates on X, Y and Z axes.



Show the cadets the slide of Figures B-1 and B-2 located at Attachment B.

- **Cylindrical robot.** Used for assembly operations, handling machine tools, spot welding, and handling die-casting machines. It is a robot whose axes form a cylindrical coordinate system.



Show the cadets the slide of Figure B-3 located at Attachment B.

- **Polar (Spherical) robot.** Used for handling machine tools, spot welding, die-casting, fettling machines, gas welding and arc welding. It is a robot whose axes form polar coordinates.



Show the cadets the slide of Figure B-4 located at Attachment B.

- **SCARA robot.** Used for pick and place work, application of sealant, assembly operations and handling machine tools. It is a robot that has two parallel rotary joints to provide compliance in a plane.



Show the cadets the slide of Figure B-5 located at Attachment B.

- **Articulated robot.** Used for assembly operations, die-casting, fettling machines, gas welding, arc welding and spray painting. It is a robot whose arm has at least three rotary joints.



Show the cadets the slide of Figure B-6 located at Attachment B.

- **Parallel robot.** One use is a mobile platform handling cockpit flight simulators. It is a robot whose arms have concurrent prismatic or rotary joints.



Show the cadets the slide of Figures B-7 and B-8 located at Attachment B.

## Machining

Computer Numerical Control (CNC) refers to a computer controller that reads computer code instructions and drives a machine tool—a powered mechanical device typically used to fabricate components by the selective removal of material from a larger block of material. The operating parameters of the CNC are altered by changing the software, making CNC machines a type of robot.

## Cutting

The most common methods of cutting used by robots are plasma cutting and oxyfuel cutting.

Plasma cutting is a process that uses a high velocity jet of ionized gas delivered from a constricting orifice. Plasma cutting takes place when a high-velocity stream of gas (plasma) is forced through a narrow torch. Plasma cutting can be performed on any type of conductive metal—mild steel, aluminum and stainless steel are some examples.

Oxyfuel cutting is a process that cuts by burning, or oxidizing, the metal it is severing. It is therefore limited to steel and other ferrous metals that support the oxidizing process.

## Assembling

Assembly robots have expanded production capabilities in the manufacturing world, making the assembly process faster, more efficient and more precise than ever before. Robots have saved workers from tedious and dull assembly line jobs, and increased production and savings in the process. One class of assembly robot is the Selective Compliant Articulated Robot for Assembly (SCARA) Robot.



Show the cadets the slide of Figure B-5 located at Attachment B.

The work characteristics of robots give them several advantages for industrial assembly, including:

- **No fatigue.** An assembly robot can work every day, every hour without pause.
- **More output.** The consistent output of a robotic system along with quality, and repeatability are unmatched even with the most challenging of applications.
- **Better performance.** Automated systems provide precise, exact performance. Many of them are equipped with vision technology to aid in production.
- **Savings.** Robot assembly systems create savings by eliminating downtime and labour costs, while increasing production and performance.

## Welding

There are two popular types of industrial welding robots; Articulating and Cartesian.

- **Articulating robots.** Employ arms and rotating joints. These robots move like a human arm with a rotating wrist at the end. This creates an irregularly shaped robotic working zone.
- **Cartesian robots.** Move in line in any of three axes (X, Y, Z). In addition to linear movement of the robot along axes there is a wrist attached to the robot to allow rotational movement. This creates a robotic working zone that is box shaped.

## EXPLORING

### Underwater Exploration

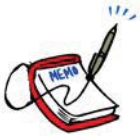


Show the cadets the slide of Figure C-1 located at Attachment C.

A seaglider is an Autonomous Underwater Vehicle (AUV) that measures temperature, salinity, depth-averaged current and other quantities in the ocean. A seaglider uses satellite data telemetry to receive commands and send the measurements it collects in near-real time. A seaglider AUV collects ocean physical properties across a range of depths and areas for oceanographers and military planners.

### Deep Space 1 (DS1)

Launched in October 1998, Deep Space 1 (DS1) was the first mission of NASA's new millennium program, chartered to validate new technologies important for future space and earth science programs. The advanced technology payload that was tested on DS1 included a solar-powered Ion Propulsion System (IPS), solar concentrator arrays, an autonomous on-board optical navigation system and an autonomous artificial intelligence (AI) system known as Remote Agent.



Show the cadets the slide of Figure C-2 located at Attachment C.



Figure C-2 shows DS1 trajectory: The dotted portion of the trajectory shows where the DS1 was coasting (ballistic flight) and the solid portion indicates where the IPS thrust was turned on, accelerating the spacecraft.

The autonomous optical navigation system on board DS1 used images of asteroids and stars collected by the onboard camera system, while the onboard navigator system computed and corrected the spacecraft's course.

The autonomous operations system was composed of an AI "agent" that planned, made decisions, and operated by itself.

## SPACE

Space-based robotic technology falls within the following three broad mission areas:

- exploration robotics,
- science payload maintenance, and
- on-orbit servicing.

Important robotic devices proven in space include:

- Remotely Operated Vehicle (ROV) such as the Mars Exploration Rovers, and
- Remote Manipulator System (RMS) such as the Canadarm.

An ROV can be an unmanned spacecraft that remains in flight, a lander that lands on a body such as a moon, asteroid or planet and operates from a stationary position, or a rover that can move over terrain once it has landed. One of the best known ROV's is the Sojourner rover that was deployed by the Mars Pathfinder spacecraft.



Show the cadets the slide of Figure C-3 located at Attachment C.

## EMERGENCY SERVICES

Robots can resolve high-risk scenarios safely, including bomb disposal, hostage situations, search and rescue and other dangerous incidents. Robots can detect explosive vapors and particulates emanating from munitions and Improvised Explosive Devices (IEDs) while keeping the operator and civilians out of harm's way. They can drive to and reach through windows, under vehicles and around obstructing objects and place ultra-sensitive explosive detectors close to suspicious packages and other potentially dangerous items.

## MILITARY

Robots can carry heavy payloads, travel over rough terrain and climb stairs while maintaining full mobility. When equipped with appropriate equipment, they can support a variety of critical missions, including:

- battlefield casualty extraction,
- Explosive Ordnance Disposal (EOD),
- vehicle-borne Improvised Explosive Device (IED) detection,
- physical security,
- firefighting,
- Special Weapons And Tactics (SWAT),
- reconnaissance,
- hazardous material handling,
- chemical-biological weapon detection,
- building clearance,
- target acquisition, and
- weaponized missions.

### Sniper Detection



Show the cadets the slide of Figure C-4 located at Attachment C.

By providing superior situational awareness, a robot can support safer ground troop movement. It can find the point of hostile gunfire without exposing ground troops, allowing them to move more safely.

---

## CONFIRMATION OF TEACHING POINT 2

### QUESTIONS:

- Q1. What are two properties of robots that make them especially desirable for certain jobs?
- Q2. What was the name of the AI on DS1?
- Q3. Name three possible military missions for robots.

### ANTICIPATED ANSWERS:

- A1. Properties of robots that make them especially desirable for certain jobs include:
  - robots never get tired;
  - robots can endure physical conditions that are uncomfortable or even dangerous;
  - robots operate in airless conditions;

- robots do not get bored by repetition; and
- robots cannot be distracted from the task at hand.

A2. Remote agent.

A3. Possible military missions for robots include:

- battlefield casualty extraction,
- EOD,
- vehicle-borne IED detection,
- physical security,
- firefighting,
- SWAT,
- reconnaissance,
- hazardous material handling,
- chemical-biological weapon detection,
- building clearance,
- target acquisition, and
- weaponized missions.

---

## END OF LESSON CONFIRMATION

### QUESTIONS:

- Q1. What two modes do robots such as the Canadarm and the Canadarm2 combine?
- Q2. What characteristics make autonomous robots different from regular machinery?
- Q3. What are five applications of robots?

### ANTICIPATED ANSWERS:

- A1. Remote control and autonomy.
- A2. Characteristics that make autonomous robots different from regular machinery are that they:
- usually function by themselves;
  - are sensitive to their environment;
  - adapt to variations in the environment or to errors in prior performance;
  - are task oriented; and
  - have the ability to try different methods to accomplish a task.
- A3. Industrial fabrication, exploration, space, emergency services, and military.

---

**CONCLUSION**

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**HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

Robots and various robotic applications are encountered every day in every walk of life. They form an important and growing aspect of the aerospace industry in both manufacturing and operations.

**INSTRUCTOR NOTES / REMARKS**

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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**REFERENCES**

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C3-292 NASA. (2003). *Rover ranch: K-12 experiments in robotic software*. Retrieved November 20, 2008, from <http://prime.jsc.nasa.gov/ROV/>



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Figure A-1 Leonardo da Vinci's Robot Drawing

*Note.* From "Z-Kat the Digital Surgery Company", by R. Abovitz, 2001, *Leonardo's Robot*, Copyright 2008 by R. Abovitz. Retrieved November 18, 2008, from [http://www.z-kat.com/company/adv\\_research/leonardo.shtml](http://www.z-kat.com/company/adv_research/leonardo.shtml)



Figure A-2 Leonardo da Vinci's Robot

*Note.* From "Z-Kat the Digital Surgery Company", by R. Abovitz, 2001, *Leonardo's Robot*, Copyright 2008 by R. Abovitz. Retrieved November 18, 2008, from [http://www.z-kat.com/company/adv\\_research/leonardo.shtml](http://www.z-kat.com/company/adv_research/leonardo.shtml)

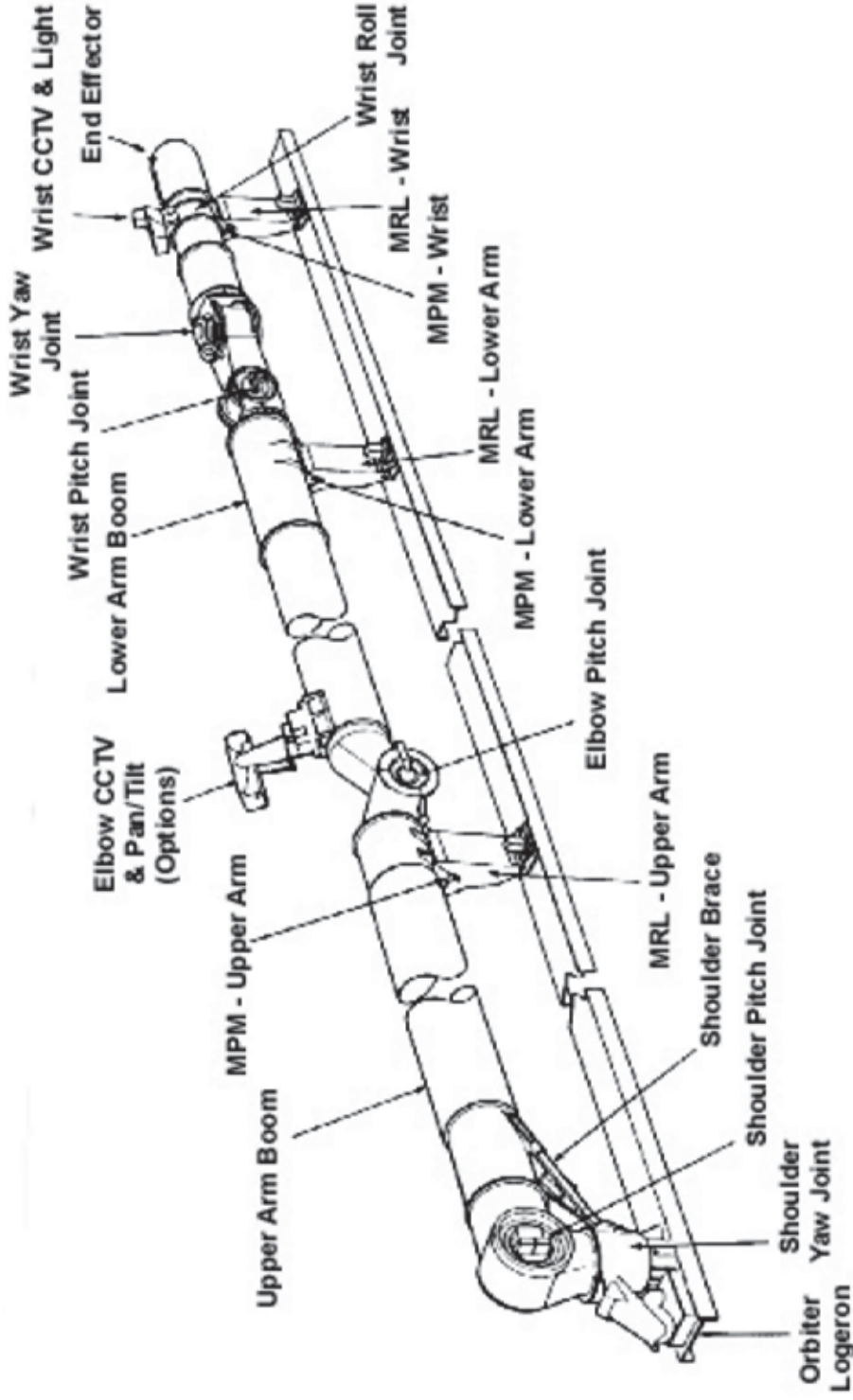


Figure A-3 Canadarm

Note. From Canadian Space Agency, 2006, *The Structure of Canadarm*. Retrieved November 18, 2008, from <http://www.asc-csa.gc.ca/eng/canadarm/description.asp>

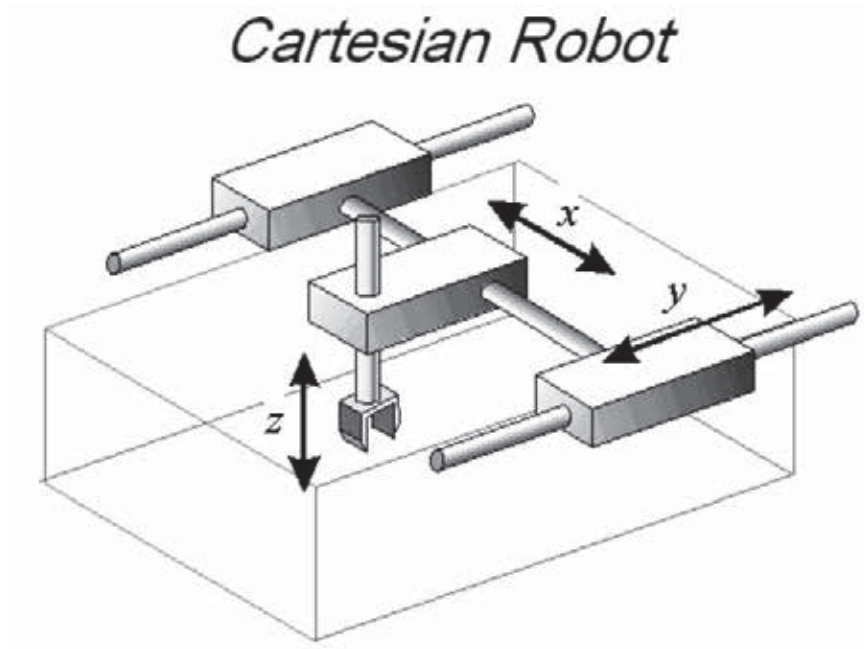


Figure B-1 Cartesian Robot

*Note.* From "ROVer Ranch K-12 Experiments in Robotic Software" by NASA, 2003, *Types of Robots*. Retrieved November 17, 2008, from <http://prime.jsc.nasa.gov/ROV/types.html>

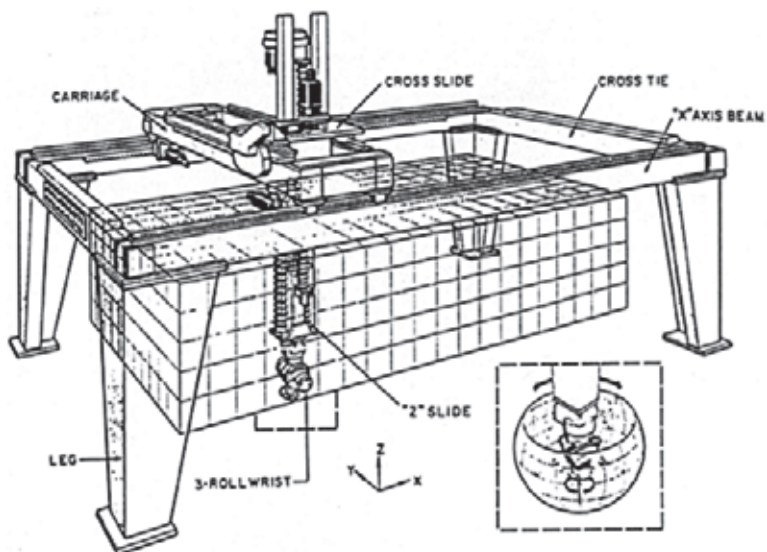


Figure B-2 Cartesian Gantry Robot

*Note.* From "ROVer Ranch K-12 Experiments in Robotic Software" by NASA, 2003, *Types of Robots*. Retrieved November 17, 2008, from <http://prime.jsc.nasa.gov/ROV/types.html>

# *Cylindrical Robot*

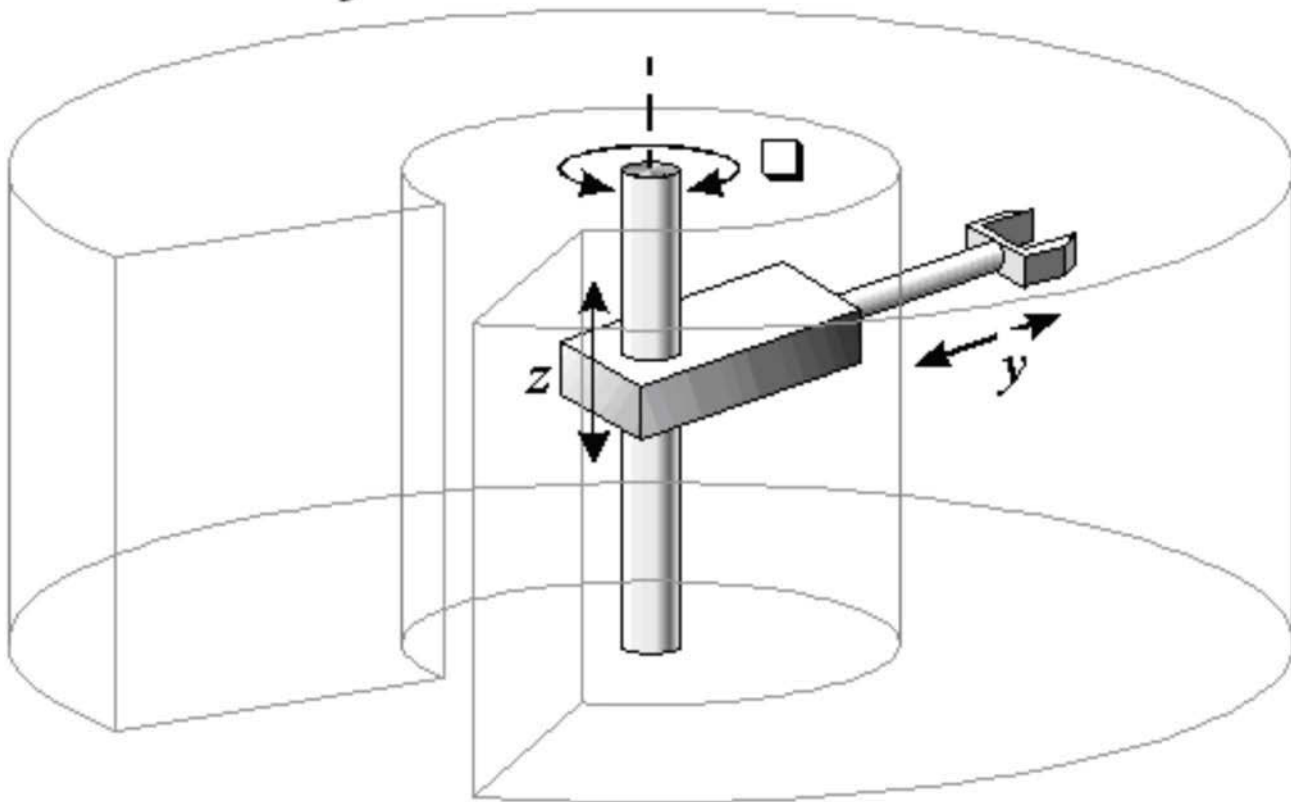


Figure B-3 Cylindrical Robot

*Note.* From "ROVer Ranch K-12 Experiments in Robotic Software" by NASA, 2003, *Types of Robots*. Retrieved November 17, 2008, from <http://prime.jsc.nasa.gov/ROV/types.html>

# *Polar Robot*

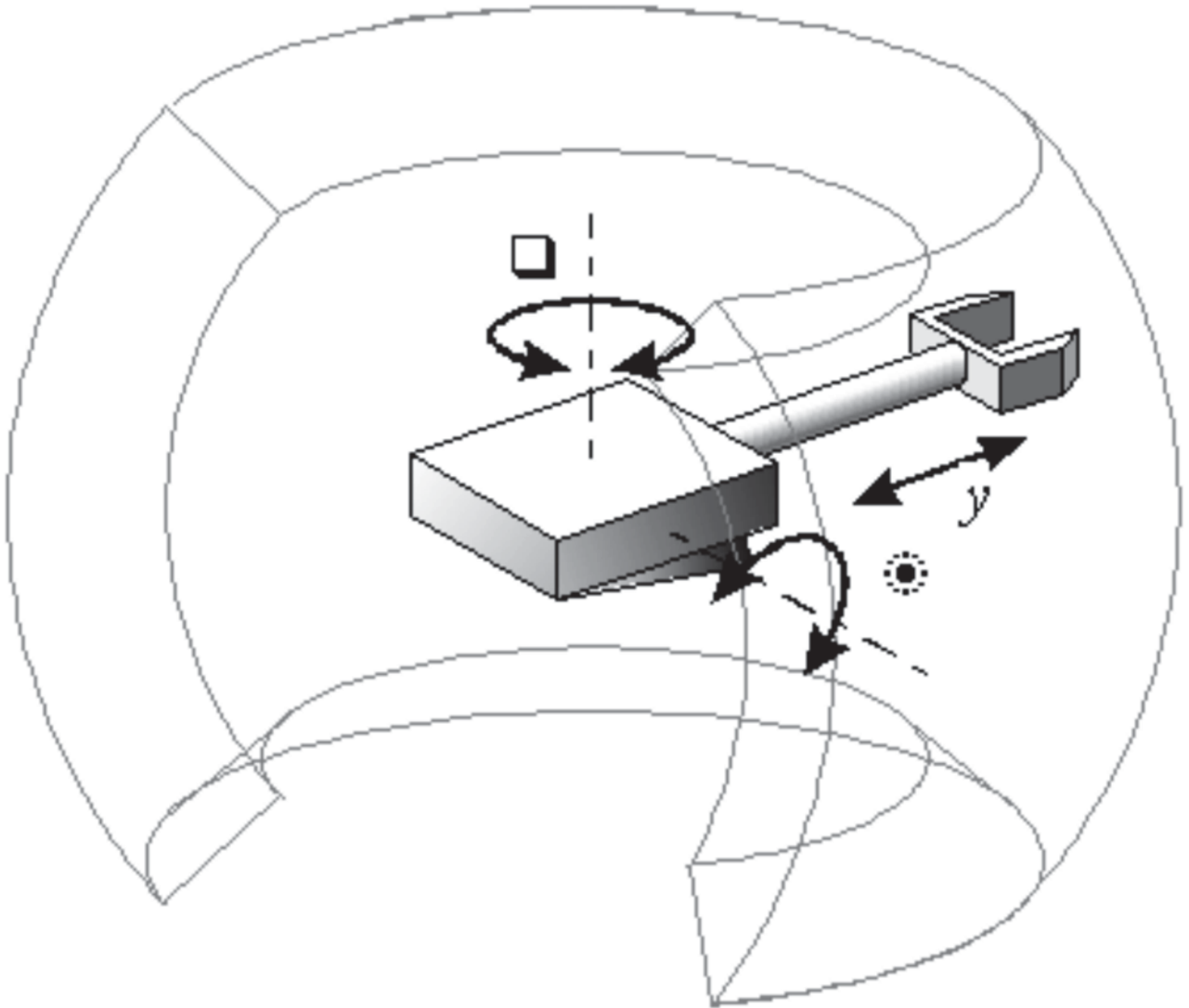


Figure B-4 Polar Robot

*Note.* From "ROVer Ranch K-12 Experiments in Robotic Software" by NASA, 2003, *Types of Robots*. Retrieved November 17, 2008, from <http://prime.jsc.nasa.gov/ROV/types.html>

## *SCARA Robot*

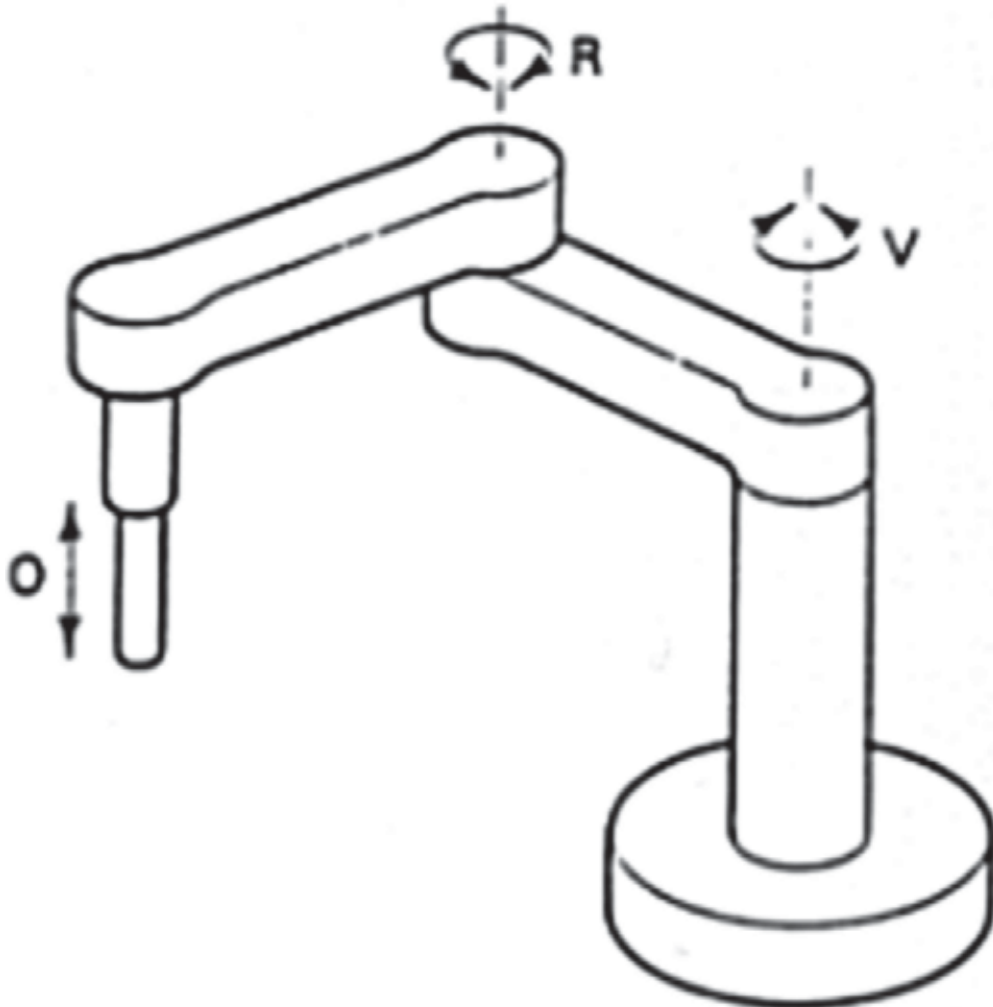


Figure B-5 Selective Compliant Articulated Robot for Assembly (SCARA) Robot

*Note.* From "ROVer Ranch K-12 Experiments in Robotic Software" by NASA, 2003, *Types of Robots*. Retrieved November 17, 2008, from <http://prime.jsc.nasa.gov/ROV/types.html>



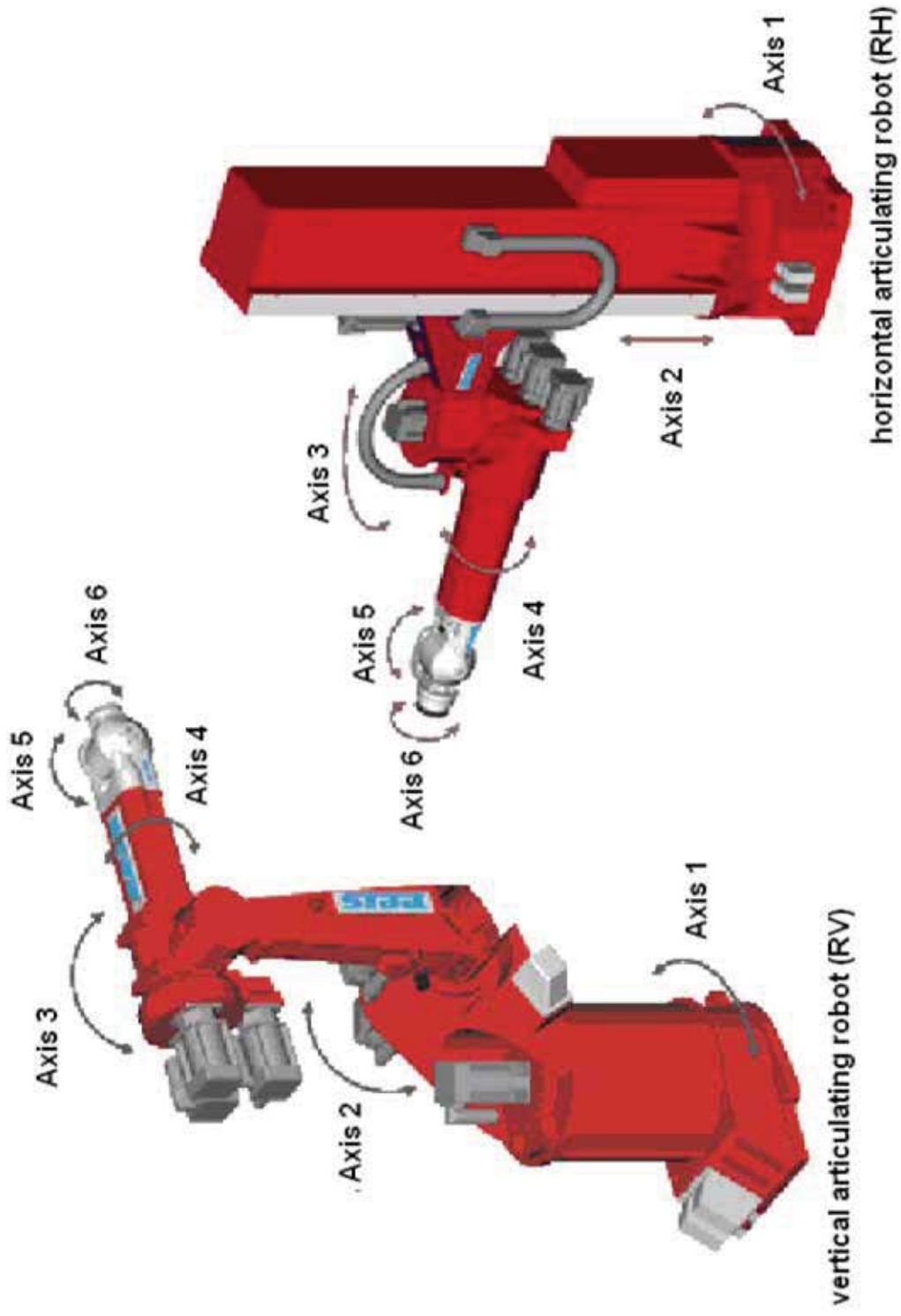


Figure B-6 Articulated Robots

Note. From "Robotics & Automation Home: Types of Robots" by Olympus Technologies Ltd., 2008, *Articulating Robots*. Retrieved November 22, 2008, from <http://www.olympustechnologies.co.uk/Robotics/types-articulating.htm>

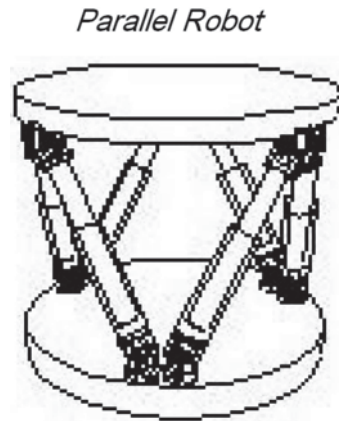


Figure B-7 Parallel Robot

*Note.* From "ROVer Ranch K-12 Experiments in Robotic Software" by NASA, 2003, *Types of Robots*. Retrieved November 17, 2008, from <http://prime.jsc.nasa.gov/ROV/types.html>

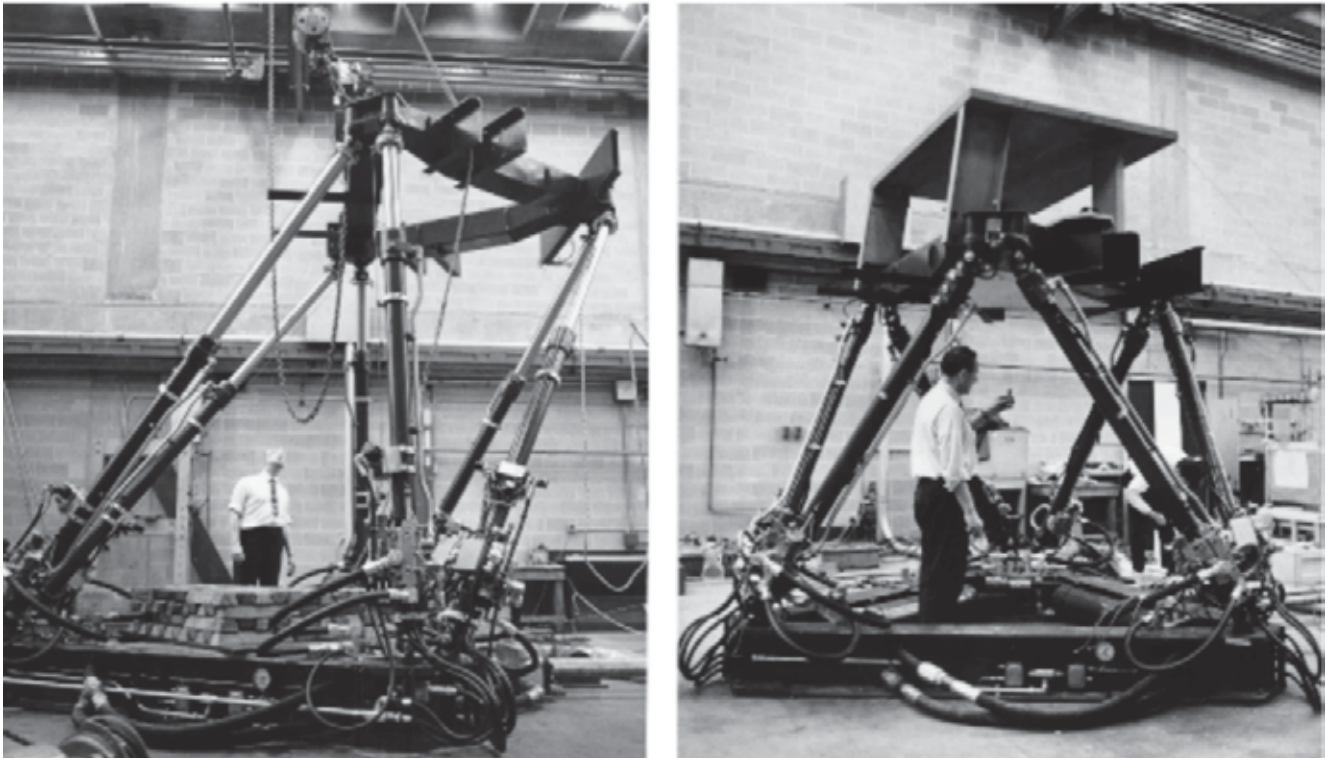


Figure B-8 Parallel Robot: An Early Flight Simulator

*Note.* From "Reviews in the Field of Parallel Mechanisms", by ParalleMIC, 2003, Copyright 2003 by Ilian Bonev, *The True Origins of Parallel Robots*. Retrieved November 22, 2008, from <http://www.olympustechnologies.co.uk/Robotics/types-articulating.htm>



Figure C-1 Seaglider

*Note.* From "Robots That Make a Difference", by iRobot, 2008, *Missions for Maritime Operations: Seaglider*, Copyright 2007, by iRobot. Retrieved November 20, 2008, from <http://www.irobot.com/sp.cfm?pageid=393>

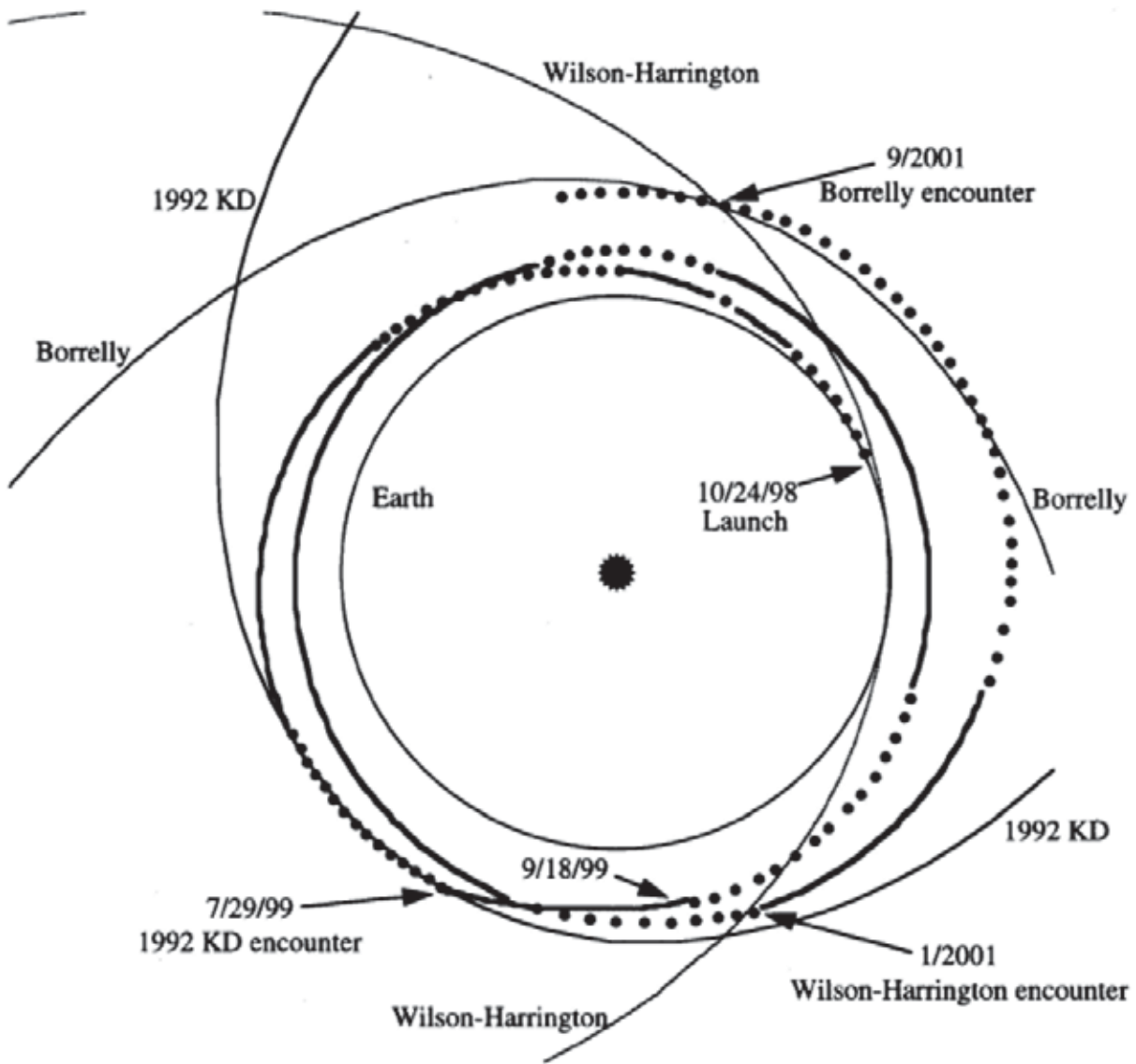


Figure C-2 DS1 Trajectory

*Note.* From *Results From the Deep Space 1 Technology Validation Mission*, by M. Rayman, P. Varghese, D. Lehman, and L. Livesay. Copyright 1999 by the American Institute of Aeronautics and Astronautics, Inc. Retrieved November 20, 2008, from [http://nmp.jpl.nasa.gov/ds1/DS1\\_Primary\\_Mission.pdf](http://nmp.jpl.nasa.gov/ds1/DS1_Primary_Mission.pdf)





Figure C-3 Self-Calibrating Pseudolite Array

Note. From "ARL Projects", by Stanford University Aerospace Robotics Laboratory, 2005, *Mars Rover Navigation Using GPS Self-Calibrating Pseudolite Arrays*. Retrieved November 20, 2008, from <http://arl.stanford.edu/>



Figure C-4 Sniper Detection

Note. From "Robots That Make a Difference", by iRobot, 2008, *Missions for Ground Forces: Sniper Protection*, Copyright 2007 by iRobot. Retrieved November 20, 2008, from <http://www.irobot.com/sp.cfm?pageid=165>



**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 8**

**EO C440.06 – USE STAR CHARTS**

Total Time:

60 min

**PREPARATION**

**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Obtain a desktop globe for use in TP 2.

Obtain planisphere star charts and red-filtered flashlights for each cadet for use in TP 4.

Create slides of Attachments A and B.

Photocopy Attachment C for each cadet.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for TPs 1–3 to introduce the cadets to star charts and give an overview of the subject.

A demonstration and performance was chosen for TP 4 as it allows the instructor to explain and demonstrate planisphere use while providing an opportunity for the cadets to practice the skill under supervision.

**INTRODUCTION**

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall have used star charts to identify elements of the night sky.

**IMPORTANCE**

It is important for cadets to be able to use star charts because this knowledge enhances the enjoyment of amateur astronomy while contributing to an understanding of the aerospace challenge.



**Teaching Point 1****Explain how the celestial sphere is divided.**

Time: 5 min

Method: Interactive Lecture

**HOW EARTH AND SKY ARE ASSUMED TO BE CONCENTRIC**

**Celestial sphere.** An imaginary sphere with the observer at its centre and celestial objects located on its inner surface.

**Concentric.** Having a common centre.

At first sight, the complexity of the night sky may seem bewildering. Familiarity with the night sky, as well as determining and describing the locations of celestial objects such as stars and galaxies, requires a standardized coordinate system. Such a system allows workers in the field to communicate celestial positions so that the observation can be repeated by others. For this purpose, a standardized coordinate system known as the celestial sphere was created. The celestial sphere is an optical illusion resulting from the inability to discern distance to stars making them all appear to be the same distance away. This imaginary sphere, therefore, is of infinite radius with the Earth located at its centre. The poles of the celestial sphere are aligned with the poles of the Earth. The celestial equator lies along the celestial sphere in the same plane that includes the Earth's equator. This is designed for the convenience of observers on Earth. The optical illusion of the celestial sphere can only be seen, in its orientation showing the classic constellations, from within the solar system.



Show the cadets the slide of Figure A-1 located at Attachment A.

When considering the celestial sphere it is convenient to assume that the sky is solid and that the celestial sphere is concentric with, or has the same centre as, the surface of the Earth.

**CELESTIAL POLES**

The north pole of the celestial sphere is the point directly above the Earth's north pole and the south pole of the celestial sphere is the point directly below the Earth's south pole. The North Celestial Pole (NCP) and the South Celestial Pole (SCP) are simply the north and south poles of the Earth extended into space.



Show the cadets the slide of Figure A-2 located at Attachment A.

The NCP passes very close to the star Polaris. As the Earth rotates around the NCP, Polaris is the only object in the sky that appears to stand still.

**CELESTIAL EQUATOR**

The celestial equator is the Earth's equator, but at a much greater radius. If the Earth's equator was a rubber band, then the celestial equator is the same rubber band just stretched away from the Earth, out to infinity.

---

**CONFIRMATION OF TEACHING POINT 1****QUESTIONS:**

- Q1. What is the celestial sphere?
- Q2. What are the NCP and the SCP?
- Q3. Where is the celestial equator located?

**ANTICIPATED ANSWERS:**

- A1. The celestial sphere is an imaginary sphere of infinite radius with the Earth located at its centre.
- A2. The North Celestial Pole (NCP) and the South Celestial Pole (SCP) are simply the north and south poles of the Earth extended into space.
- A3. The celestial equator lies along the celestial sphere in the same plane of the Earth's equator.

---

**Teaching Point 2****Explain how the sphere of the sky is represented on star charts.**

Time: 5 min

Method: Interactive Lecture

We can locate any object on the celestial sphere by giving it two coordinates, one called the object's declination and the other the object's right ascension. These are the object's celestial coordinates.



Show the cadets the slide of Figure A-1 located at Attachment A.

**DECLINATION**

The structure of the celestial coordinate lines is almost identical to that of the coordinates of the Earth's surface. To prevent confusion, the Earth's lines of latitude are re-labelled as "declination" lines when applied to the celestial sphere, but are numbered in degrees exactly the same as the Earth lines of latitude. However, to further avoid confusion, the celestial lines of declination are marked with a plus sign (+) in place of North and a minus sign (-) in place of South. Therefore, when a declination is shown as a negative number it is in the southern half of the celestial sphere.



Parts of the southern celestial sphere can be seen from Earth's northern hemisphere, especially during the northern hemisphere's winter months. The brightest star in the sky, Sirius, at minus 20 degrees, can be seen from Canada in the winter because, just as the northern hemisphere is inclined toward the North in the daytime, it is inclined toward the South in the nighttime.



Use a globe to show the cadets how the northern hemisphere in winter changes from northern daytime skies to southern nighttime skies as night falls.

## RIGHT ASCENSION

To further prevent confusion, the longitude lines have been re-labelled as "right ascension" lines, and renumbered from 0 to 24 in hours. There is only an indirect connection to time here, even though hours, minutes and seconds are used to divide the angular distances between lines of right ascension. However, the celestial sphere, observed from the surface of Earth, is seen to complete one complete rotation overhead approximately once every 24 hours. Celestial rotation would be 24 hours exactly, if it were not for Earth's orbit around the Sun.

The right ascension of an object on the celestial sphere is measured along the celestial equator. By convention, 0 degrees is the point on the celestial equator where the Sun is found on the first day of spring (the vernal equinox).



Notice that 0 hours right ascension is unrelated to 0 degrees longitude. Using hours instead of degrees neatly avoids this conflict.

Stars and galaxies have (almost) fixed positions in right ascension and declination. The Sun and planets, on the other hand, move among the distant stars so that their coordinates change throughout the year. Due to the Earth's yearly orbital motion around the Sun, the Sun appears to circle the ecliptic.

## THE PLANE OF THE ECLIPTIC

**Plane of the ecliptic.** The plane of the Earth's orbit around the Sun.

The plane of the ecliptic is an imaginary plane in which the Earth orbits the Sun. It is used as the primary reference plane when describing the position of bodies in the solar system.



Show the cadets the slide of Figure B-1 located at Attachment B.

Most objects in the solar system orbit in roughly this plane and in the same direction around the Sun as the Earth. There are exceptions such as many comets and a few minor planets (including the dwarf planet, Pluto), which have high inclinations, or tilt, compared to the reference plane—the plane of the ecliptic. Some comets even have retrograde orbits, such as Halley's comet, and orbit in the opposite direction to the planets.



Show the cadets the slide of Figure B-2 located at Attachment B.

The celestial sphere, viewed from Earth, shows the constellations that define the zodiac. The signs of the zodiac are the constellations that lie near the plane of the ecliptic and are visible at night in the months associated with these constellations.



Ask the cadets what the approximate date is in Figure B-2 located at Attachment B.

---

## CONFIRMATION OF TEACHING POINT 2

### QUESTIONS:

- Q1. What are a celestial object's two coordinates called?
- Q2. On what is a celestial object's right ascension measured?
- Q3. What is the plane of the ecliptic?

### ANTICIPATED ANSWERS:

- A1. Right ascension and declination.
- A2. The celestial equator.
- A3. The plane of the Earth's orbit around the Sun.

---

## Teaching Point 3

**Explain how to interpret a star chart.**

Time: 5 min

Method: Interactive Lecture

---

A star chart is a map of the night sky. With it, you can identify and locate constellations and stars. A typical star chart shows the relative positions of the stars and their brightness.

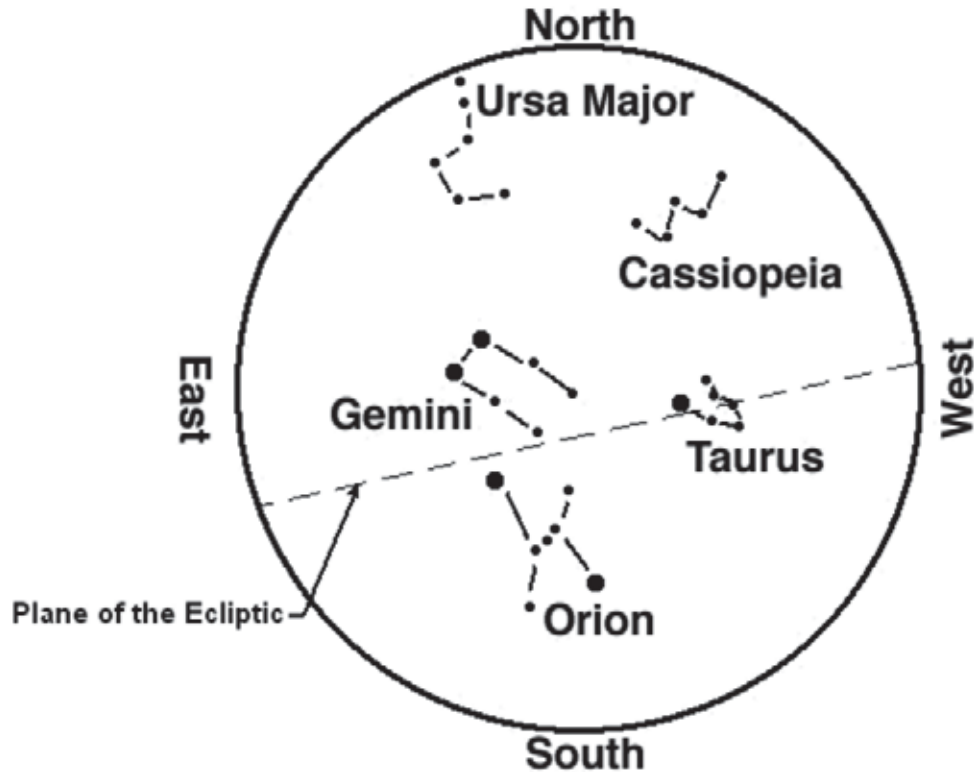


Figure 1 A Northern Hemisphere Spring Star Chart

*Note.* From "Astronomy Department at the University of Massachusetts", by T. Arny, 2002, *Using a Star Chart*, Copyright 2002, by T. Arny. Retrieved November 4, 2008, from [http://www.astro.umass.edu/~arny/constel/constel\\_tutmod.html](http://www.astro.umass.edu/~arny/constel/constel_tutmod.html)

## DATE

A star chart is accurate only on a specific date because the night sky changes as Earth follows its orbit around the Sun. Also, planets move over a period of days.

## TIME

A star chart will be correct for a very short time because celestial objects rise above the eastern horizon and follow a path overhead before finally setting in the West. Since different celestial objects are constantly rising and passing overhead and setting, a different set of celestial objects will occupy the sky at different times. The date and time of exact accuracy should be printed on the chart.

## LATITUDE

An observer on the ground can only see the sky above the horizon. Different locations on the planet have different views of the sky. Although a patient observer can wait for a certain celestial object to rise in the East, and a celestial object with a certain right ascension will eventually appear if it is at an observable declination, there are celestial objects that are not in an observable declination for a given Earth latitude. For example, Polaris, the North Star, will never be seen from the Earth's South Pole. Therefore, a star chart has a property known as latitude and it will only show the sky that can be seen at the Earth latitude for which the star chart was prepared. The star chart's Earth latitude is printed on the star chart.

## ORIENTATION

For orientation, a star chart is held overhead and turned until the direction the observer is facing appears at the bottom. If the observer is facing south, the star chart, when held overhead, should be turned until South is on

the bottom of the star chart. At this point, the pattern of celestial objects shown on the star chart will correspond to the pattern of celestial objects seen in the sky.

## PLANETS

Planets add another layer of challenge to interpreting a star chart. Planets constantly change their position relative to fixed celestial objects.



Star charts can be retrieved from the Montreal Planetarium website:  
<http://www.planetarium.montreal.qc.ca/Information/Documents/PDF/PocketPlanetariumV12N4.pdf> and other websites, such as <http://skymaps.com/downloads.html>

---

## CONFIRMATION OF TEACHING POINT 3

### QUESTIONS:

- Q1. What are two reasons that a star chart is accurate only on a specific date?
- Q2. Why is a star chart accurate only at a specific hour?
- Q3. For orientation, how is a star chart held?

### ANTICIPATED ANSWERS:

- A1. The night sky changes as Earth follows its orbit around the Sun and planets constantly move.
- A2. The night sky changes as Earth rotates on its axis.
- A3. For orientation, a star chart is held overhead and turned until the direction the observer is facing appears at the bottom.

---

## Teaching Point 4

**Explain, demonstrate and have the cadets identify elements of the night sky by exploring aspects of a planisphere.**

Time: 40 min

Method: Demonstration and Performance

**Planisphere star chart.** Analog computer for calculating the position of stars.



Distribute a planisphere star chart to each cadet.

A planisphere consists of two layers: a star map base and an overlay in which is set a clear oval window. The four steps to orienting a planisphere are as follows:

1. Locate the date, on the star map layer, on which the planisphere is to be used.
2. Rotate the overlay so that the time of use aligns with the date of use.
3. Identify North by locating the North Star.
4. The planisphere is then held above the user's head, map downward, with the middle of the oval window directly overhead and the midnight time mark toward the North.

The coordinates of a celestial object shown on a planisphere can be determined by reading the hours of right ascension from the outer edge of the star map base. Lines of right ascension run from the edge of the star map base to the centre of the star map base. A celestial object's declination can be determined by interpolating between the concentric declination lines which circle the star map base, with the celestial equator shown at 0 degrees—passing through constellation Orion at 6 hours right ascension.



Instruct the cadets on how to use the specific planisphere star chart according to directions provided with the planisphere.

Planispheres generally have the following characteristics:

- a. **Planisphere design.** A planisphere has this name because the celestial sphere is represented on a flat plane, such as paper. Since the Earth is constantly in motion, the time of day, time of year, and location influence the appearance of the sky. An individual star chart cannot accurately represent all of these combinations. This would take many different star charts. A preferable method is to use a planisphere star chart that allows the user to twist a dial to show the true position of the stars.
- b. **The lack of planetary data on a planisphere.** Since the planisphere is usable on any day, it cannot display planets because planets constantly move across the sky.
- c. **Date.** The visible night time stars and constellations change as the Earth revolves around the Sun. The summer sky is therefore different than the winter sky because the Earth is facing the opposite direction. Therefore, the correct date must be selected on the planisphere.
- d. **Time.** As the Earth turns on its axis, stars and constellations rise in the East and set in the West, just as the Sun does (the Sun is just one more star, but a close one). Therefore, the planisphere must be adjusted for correct time.
- e. **Midnight time mark.** When applying the planisphere to the night sky, the planisphere is oriented so that the midnight mark is to the North, after the time of day on the overlay is aligned with the date on the star map base.
- f. **Latitude.** Planispheres are specific to latitudes because each latitude allows a view of a different swath of the celestial sphere as the Earth rotates.
- g. **Orientation.** For constellations to appear in their correct location on the planisphere at the correct time, it is necessary to align the planisphere correctly with True North. When that is done, constellations that are rising in the East will be shown on the east edge of the planisphere. The planisphere consists of two layers: a star map base and an overlay in which is set a clear oval window.
- h. **Horizon.** The edges of the clear overlay window represent the viewer's approximate horizon.
- i. **Constellations.** On most planispheres, the names of constellations are printed in capital letters.
- j. **Stars.** On most planispheres, the names of stars are printed in lower case letters, except the first letter in the star's name, which is capitalized.



---

## ACTIVITY

Time: 30 min

### OBJECTIVE

The objective of this activity is to have the cadets identify elements of the night sky by exploring aspects of a planisphere.

### RESOURCES

- Observation Record located at Attachment C,
- Planispheres, and
- Red-filtered flashlights.

### ACTIVITY LAYOUT

- For the demonstration portion of this lesson, organize the cadets into a circle with the instructor as a member of the circle.
- For the performance portion of this lesson, the cadets keep within hearing distance of the instructor so the instructor can easily respond to questions.

### ACTIVITY INSTRUCTIONS

1. Distribute a photocopy of Attachment C to each cadet.
2. Distribute one red-filtered flashlight per four cadets and have the cadets orient their planispheres.
3. Have the cadets locate celestial objects and constellations, using a planisphere.
4. Have the cadets determine the coordinates of celestial objects by reading declination and right ascension from the star base map of the planisphere, including interpolation between the coordinate lines.
5. Have the cadets record their observations of the celestial sphere on Attachment C.

### SAFETY

Nil.

---

### CONFIRMATION OF TEACHING POINT 4

The cadets' participation in identifying elements of the night sky by exploring aspects of a planisphere will serve as the confirmation of this TP.

---

### END OF LESSON CONFIRMATION

### QUESTIONS

- Q1. What is the celestial sphere?
- Q2. Why are planispheres specific to latitudes on Earth?
- Q3. Where does the name planisphere come from?

### **ANTICIPATED ANSWERS**

- A1. The celestial sphere is an imaginary sphere of infinite radius with the Earth located at its centre.
- A2. Planispheres are specific to latitudes on Earth because each latitude allows a view of a different swath of the celestial sphere as the Earth rotates.
- A3. A planisphere has this name because the celestial sphere is represented on a flat plane, such as paper.

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### **CONCLUSION**

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### **HOMEWORK / READING / PRACTICE**

Nil.

### **METHOD OF EVALUATION**

Nil.

### **CLOSING STATEMENT**

Knowledge of how to use a star chart is very helpful in amateur astronomy and will aid in the identification of many celestial bodies that would otherwise be missed.

### **INSTRUCTOR NOTES / REMARKS**

TPs 1–3 may be taught in the classroom or in the field, as appropriate.

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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### **REFERENCES**

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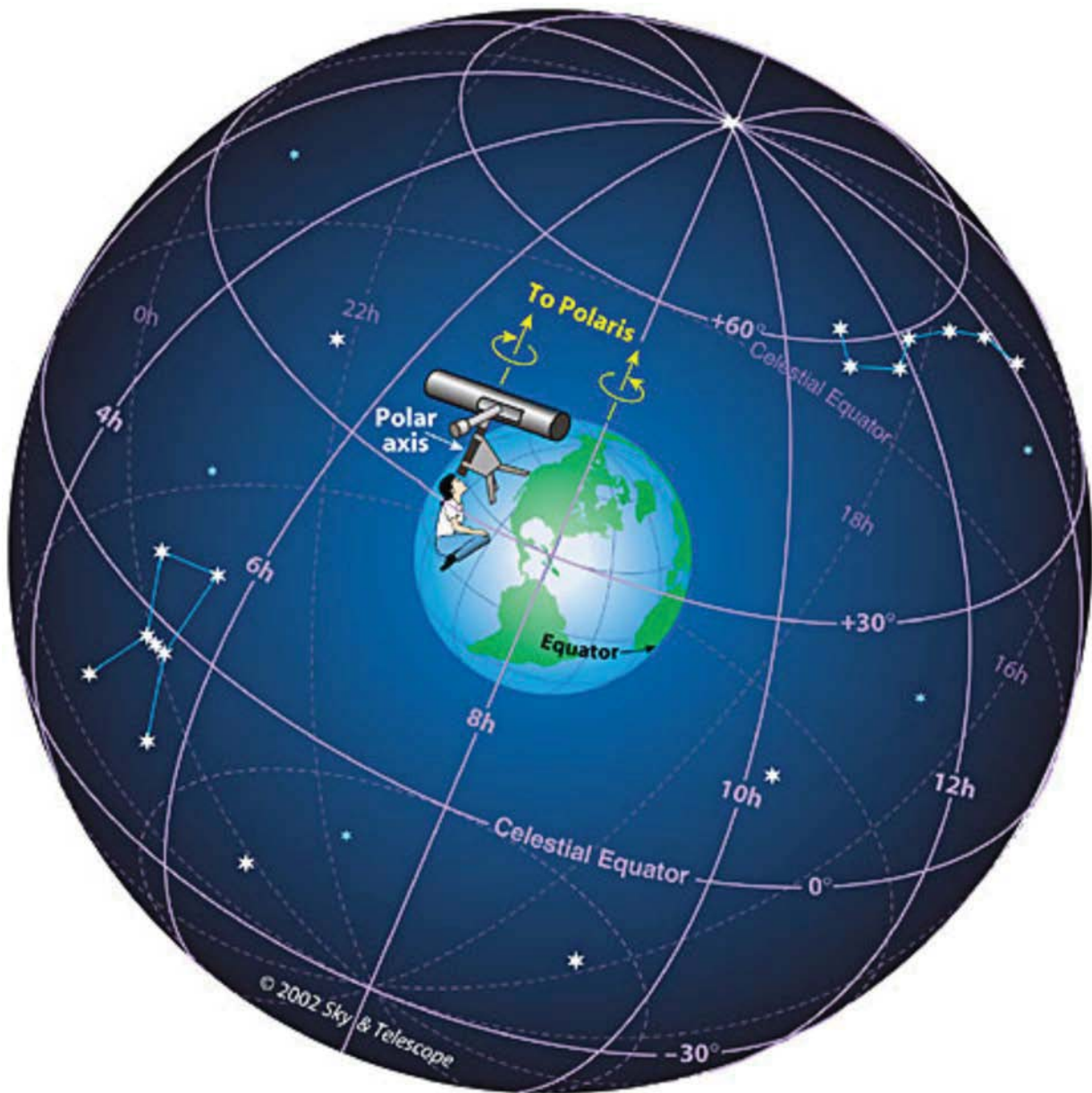


Figure A-1 Aligning With Polaris

Note. From "Sky and Telescope" by A. M. MacRobert, 2001, *Understanding Celestial Coordinates*. Retrieved October 30, 2008, from [http://www.skyandtelescope.com/howto/basics/Celestial\\_Coordinates.htm](http://www.skyandtelescope.com/howto/basics/Celestial_Coordinates.htm)



Figure A-2 Observing Polaris

*Note.* From "Sky and Telescope" by A. M. MacRobert, 2001, *Understanding Celestial Coordinates*. Retrieved October 30, 2008, from [http://www.skyandtelescope.com/howto/basics/Celestial\\_Coordinates.html](http://www.skyandtelescope.com/howto/basics/Celestial_Coordinates.html)

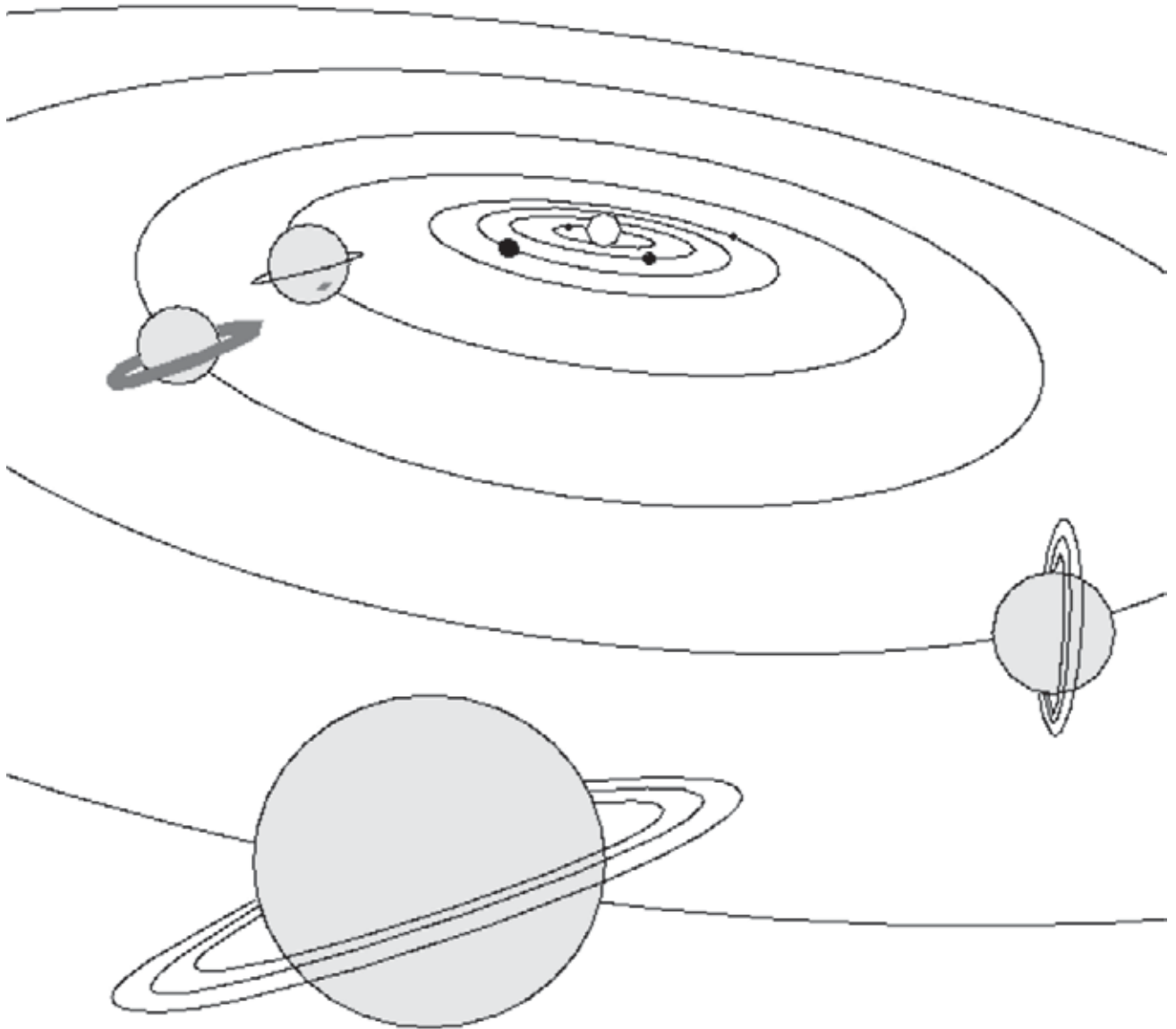


Figure B-1 Third Rock from the Sun

*Note.* From "CSE@SSL", by B. Napier, 1995, *Demonstration: The Plane of the Ecliptic*, Copyright 1995 by Regents of the University of California. Retrieved October 30, 2008, from <http://cse.ssl.berkeley.edu/img/eclip.gif>



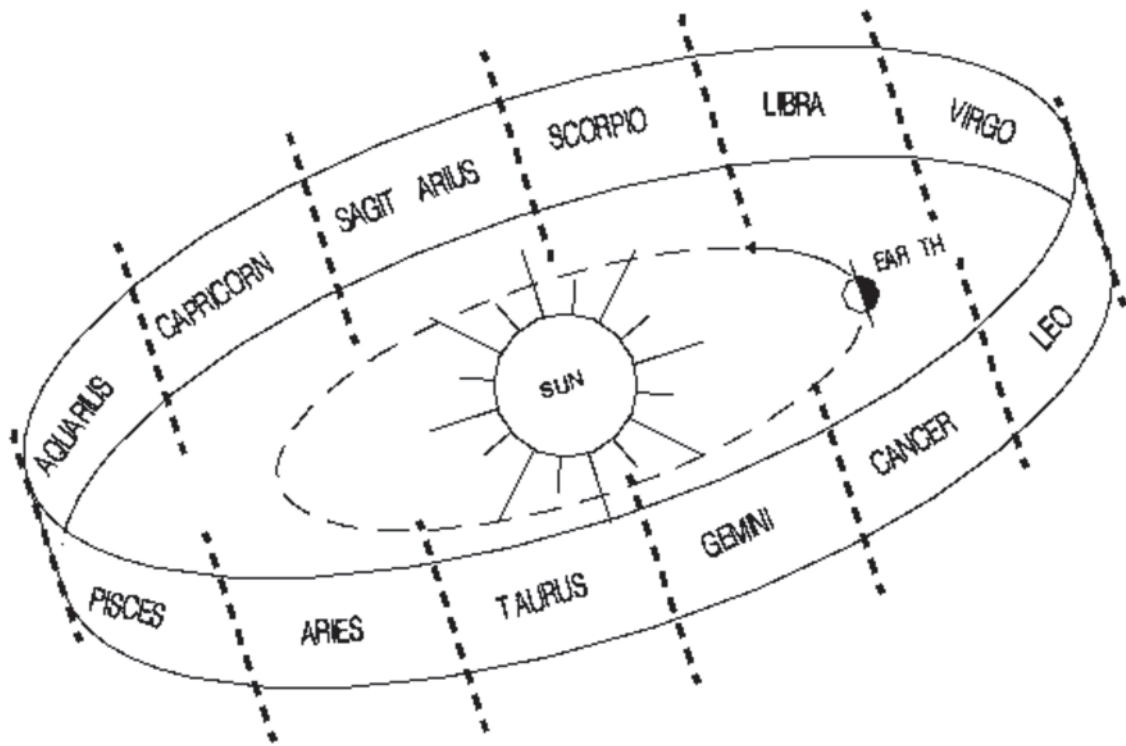


Figure B-2 The Zodiac and its Constellations

Note. From "CSE@SSL", by B. Napier, 1995, *Demonstration: The Plane of the Ecliptic*, Copyright 1995 by Regents of the University of California. Retrieved October 30, 2008, from [http://cse.ssl.berkeley.edu/lessons/indiv/beth/beth\\_intro.html](http://cse.ssl.berkeley.edu/lessons/indiv/beth/beth_intro.html)

Observation Record	
Date:	Time:
Place:	Instruments used:
Conditions:	
Observations:	



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**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 9**

**EO C440.07 – OPERATE A TELESCOPE**

Total Time:

60 min

**PREPARATION**

**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of figures located at Attachments A and B.

Check that all equipment for TP 3 is serviceable prior to delivering the lesson.

Check the telescope's owner's manual for use procedures and modify the lesson as required.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for TPs 1 and 2 to orient the cadets to telescope theory and generate interest in the subject.

A demonstration and performance was chosen for TP 3 as it allows the instructor to explain and demonstrate the telescope-handling skills the cadets are expected to acquire while providing an opportunity for the cadets to practice the skill under supervision.

**INTRODUCTION**

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to operate manual and computerized telescopes.

**IMPORTANCE**

It is important for cadets to know how to operate telescopes because this provides a fascinating way to become personally involved with astronomy—an important aspect of aerospace development.

---

**Teaching Point 1****Identify the parts of a telescope.**

Time: 10 min

Method: Interactive Lecture

---



Show the cadets Attachment A and use a telescope as an example, to show where the parts of a telescope are located.

Many telescopes have the following parts and accessories:

**Optical tube.** Forms the body of the telescope.

**Optical tube mounts.** These include:

- equatorial mount (one axis of movement on the Earth's equatorial plane), and
- altazimuth mount (two axes of movement—altitude and azimuth).

**Finderscope.** Used to orient the main telescope.

**Eyepiece.** Used to focus the gathered star light for the human eye.

**Lens cover.** Used to protect the telescope optics when stored.

**Mirrors.** Used to reflect and concentrate light.

**Lens(es).** Used to refract (or change the path of) light.

**Focus knob.** Used to focus the light in the telescope.

**Tripod.** Used to provide a firm, steady base for the telescope.

**Specialty computerized telescope parts.** These include:

- control panel,
- on / off switch,
- computer interface port, and
- power cord.

---

**CONFIRMATION OF TEACHING POINT 1****QUESTIONS:**

- Q1. How many axes of movement does an equatorial mount have?
- Q2. What is the purpose of a finderscope?
- Q3. What is the purpose of a lens?

**ANTICIPATED ANSWERS:**

- A1. One axis of movement.
- A2. A finderscope is used to orient the main telescope.
- A3. A lens is used to refract (or change the path of) light.

**Teaching Point 2****Describe telescope theory.**

Time: 10 min

Method: Interactive Lecture

**SAFETY**

An observer must never look at the sun through an unfiltered lens because the focused sunlight will seriously damage a human eye.

Telescopes are fragile equipment requiring careful handling. Rough handling will not only damage the telescope, but may break the glass.

**WHAT THE NUMBERS REPRESENT****Light Gathering of Main Lens or Mirror (Aperture)**

The main lens or mirror of a telescope is referred to as the telescope's objective. The size of a telescope's objective determines the telescope's aperture. The larger the aperture of a telescope, the more light it can gather in a given unit of time. This not only makes certain features more visible to the human eye, it also shortens exposure times for celestial photography. A 30-cm (12-inch) main mirror produces images nine times brighter than a 10-cm (4-inch) mirror. Large telescopes are more difficult to move and handle, but smaller telescopes require longer exposure times for celestial photography.

**Focal Length**

Focal length is the distance that the main lens or mirror of a telescope takes to focus light to the point of focus. The longer the focal length, the larger the image at the focal point. This can be made up on a short focal length telescope, in most cases, by the magnification of the eyepiece. Although a long focal-length telescope produces a larger image at focus, it will also be fainter because the long focal path spreads out the light. During photography, when no eyepiece is used, a longer focal length is sometimes an advantage because it yields a larger image with comparable magnification.



The magnifying power of a telescope can be changed by changing the eyepiece (also referred to as the ocular). To determine the magnification of a telescope, divide the focal length of the telescope by the focal length of the eyepiece being used.

**Focal Ratio**

Focal ratio is the ratio of a telescope's focal length to the diameter of its main lens or mirror—its objective. Focal ratio is found by dividing focal length by objective diameter (aperture). A telescope with a mirror of 20 cm (8 inches) across and a focal length of 122 cm (48 inches) has a focal ratio of  $f/6$ . A telescope's focal length can be found by multiplying focal ratio by aperture, so that a telescope with a 20-cm (8-inch) aperture and  $f/6$  ratio would have a focal length of 122 cm (48 inches).

Long focal lengths are considered to be in the  $f/9$  or greater range. A telescope of a given diameter coupled with a short focal length produces bright images but wide fields. This is fine for observing large deep-sky objects and

star fields, but to photograph planets and binary stars, a longer focal length is superior because the planet's or binary's image is larger at the point of focus.

## **SEEING**

Seeing refers to the steadiness of the image of a celestial object viewed through the telescope. Good seeing means a steady image, while bad seeing means an unsteady image. Binoculars, which typically have much less magnification, can tolerate greater shaking movement without degraded seeing. It is the image, which is viewed, that determines seeing.

### **Image Shaking**

Any movement of the telescope while viewing will degrade seeing. Heavier tripods tend to provide a steadier base for a telescope and improve seeing. Spindly tripods tend to degrade seeing by allowing the telescope to shake during use.

### **Shimmering (Atmospheric Turbulence)**

Turbulence in the Earth's atmosphere imparts a shimmering quality to telescope images. This is the same effect which makes stars appear to twinkle to the naked eye. The intensity of the turbulence depends on winds, the temperature differential among upper-atmosphere layers and the local topography and air circulation immediately around the telescope. The larger the diameter of the telescope, the more it is affected, because large telescopes have to peer through more air than smaller ones do. A telescope with a main lens or mirror 20 cm (8 inches) in diameter must look through a column of air 20 cm (8 inches) wide and about 16 km (10 miles) long.

## **THREE MAIN TYPES OF TELESCOPE OPTICAL SYSTEMS**

### **Refractor Telescope**

Although the classic design of the refractor has undergone significant changes since Galileo's time, the principle is still the same.

A main lens composed of two or more different pieces of optically figured glass brings light to a focus at the opposite end of the tube. Refractors have the advantage of rendering sharp high-contrast images, large image scales (due to higher focal ratios) and excellent resolution.

### **Newtonian Reflector Telescope**

Since its invention by Sir Isaac Newton in 1668, the reflector telescope has been very popular with amateur astronomers. It consists of a concave mirror positioned at the bottom of the tube that reflects and focuses starlight to a point just inside the tube's entrance. A flat secondary mirror redirects the light out the side of the tube and into an eyepiece lens.

Newtonian reflector telescopes provide accurate colour rendition of celestial objects and are less expensive for a given objective size than refractors. A 20-cm (8-inch) reflector costs about the same as a modest 10-cm (4-inch) refractor.

### **Schmidt-Cassegrain Telescope**

Telescopes that employ the features of both refractors and reflectors are said to be catadioptric. One of the most popular catadioptric designs is the Schmidt-Cassegrain telescope (SCT).



Show the cadets Attachment B.

The SCT has a spherical primary mirror at one end of the tube and a correcting lens at the other. The secondary mirror is mounted directly onto the correcting lens (or plate). This, in turn, redirects the light back down the tube and through a hole in the centre of the main mirror, where the eyepiece is located.

Folding the light path allows a manufacturer to produce a telescope with a focal length that is twice the length of the tube. Thus, SCTs are lightweight, portable, and produce excellent images.

---

### CONFIRMATION OF TEACHING POINT 2

#### QUESTIONS:

- Q1. Why must one never look at the sun through an unfiltered lens?
- Q2. What is seeing?
- Q3. What are three advantages of SCTs?

#### ANTICIPATED ANSWERS:

- A1. Focused sunlight will seriously damage a human eye.
- A2. Seeing refers to the steadiness of the image of a celestial object viewed through the telescope.
- A3. SCTs are lightweight, portable, and produce excellent images.

---

### Teaching Point 3

**Explain, demonstrate and have the cadets set up, operate and dismantle a telescope.**

Time: 30 min

Method: Demonstration and Performance

---



For this skill TP, it is recommended that instruction take the following format:

1. Explain and demonstrate the complete skill while cadets observe.
2. Explain and demonstrate each step required to complete the skill. Monitor cadets as they imitate each step.
3. Monitor the cadets' performance as they practice the complete skill.

Note: Assistant instructors may be employed to monitor the cadet's performance.

1. To set up a telescope:
  - a. remove all parts from their containers, ensuring that the optical tube is placed on a sturdy level surface;
  - b. set up the tripod;
  - c. attach the telescope to the tripod;

- d. attach the finderscope (if required);
  - e. attach the eyepiece (if required);
  - f. align the finderscope; and
  - g. align the telescope.
2. To operate and dismantle a telescope:
- a. adjust the right ascension;
  - b. adjust the declination;
  - c. remove the eyepiece (if required);
  - d. remove the finderscope (if required);
  - e. remove the telescope from its tripod;
  - f. collapse the tripod; and
  - g. return all parts to their containers.

Cadets must be careful when handling fragile equipment.

---

### **CONFIRMATION OF TEACHING POINT 3**

The cadets' participation in setting up, operating and dismantling telescopes will serve as the confirmation of this TP.

---

### **END OF LESSON CONFIRMATION**

#### **QUESTIONS:**

- Q1. How many axes of movement does an altazimuth mount have?
- Q2. Who invented the Newtonian reflector telescope design and in what year was it invented?
- Q3. What does folding the light path in a SCT allow the manufacturer to do?

#### **ANTICIPATED ANSWERS:**

- A1. Altazimuth mounts have two axes of movement.
- A2. Sir Isaac Newton in 1668.
- A3. Folding the light path allows a manufacturer to produce a telescope with a focal length that is twice the length of the tube.

---

### **CONCLUSION**

---

### **HOMEWORK / READING / PRACTICE**

Nil.



## **METHOD OF EVALUATION**

Nil.

## **CLOSING STATEMENT**

Knowing how to operate telescopes provides a fascinating way to become personally involved with an important aspect of aerospace development.

## **INSTRUCTOR NOTES / REMARKS**

Cadets who are qualified Advanced Aerospace may assist with this instruction.

---

## **REFERENCES**

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C3-179 ISBN 1-55209-302-6 Dickenson, T. (2001). *Night watch: A practical guide to viewing the universe*. Willowdale, ON: Firefly Books.

C3-286 11073-INST. Celestron. (2006). *CPC series instructional manual*. Torrance, CA: Celestron.

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1	Control Panel (see below)	8	Optical Tube
2	Focus Knob	9	Schmidt Corrector Lens
3	Star Diagonal	10	Fork Arm
4	Hand Control	11	Carrying Handle
5	Eyepiece	12	Right Ascension Locking Knob
6	Finderscope	13	Tripod
7	Finderscope Quick Release Bracket	14	Accessory Tray / Center Support Bracket
A	Hand Control Port	D	Auto Guider Port
B	Auxiliary Ports	E	On/Off Switch
C	PC Interface Port	F	12v Input Jack

Figure A-1 Celestron Telescope

Note. From Celestron®, 2006, CPC™ Series Instructional Manual. Copyright 2006 by Celestron, Torrance, CA: Celestron.

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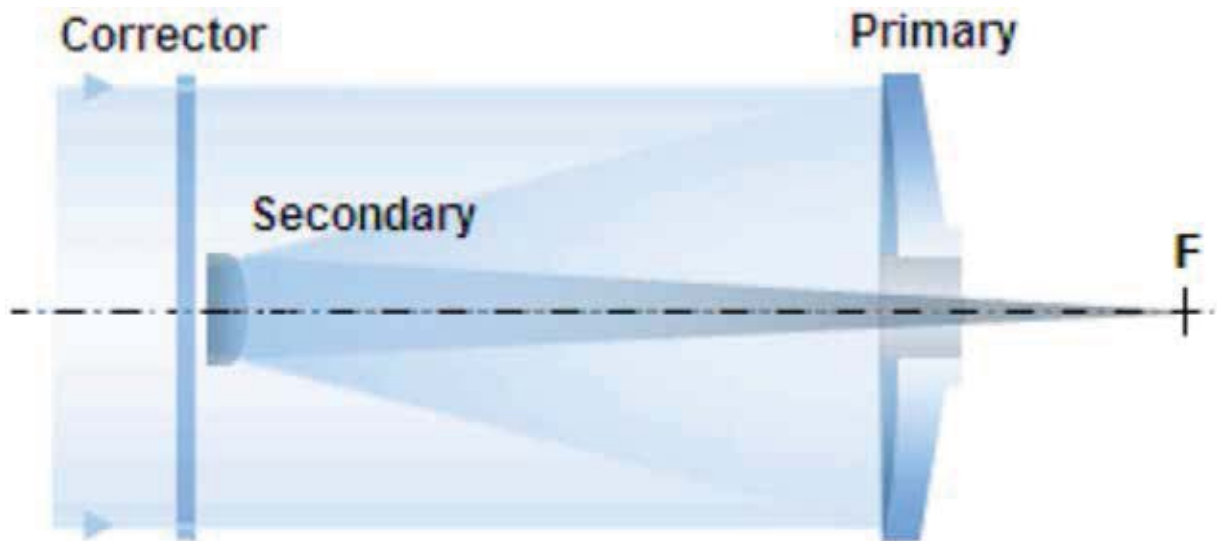


Figure B-1 Schmidt-Cassegrain Telescope Design

Note. From "telescopeOptics.net", by Vladimir Sacek, 2006, *Schmidt-Cassegrain Telescope (SCT)* Retrieved October 15, 2008, from <http://www.telescope-optics.net/SCT.htm>.

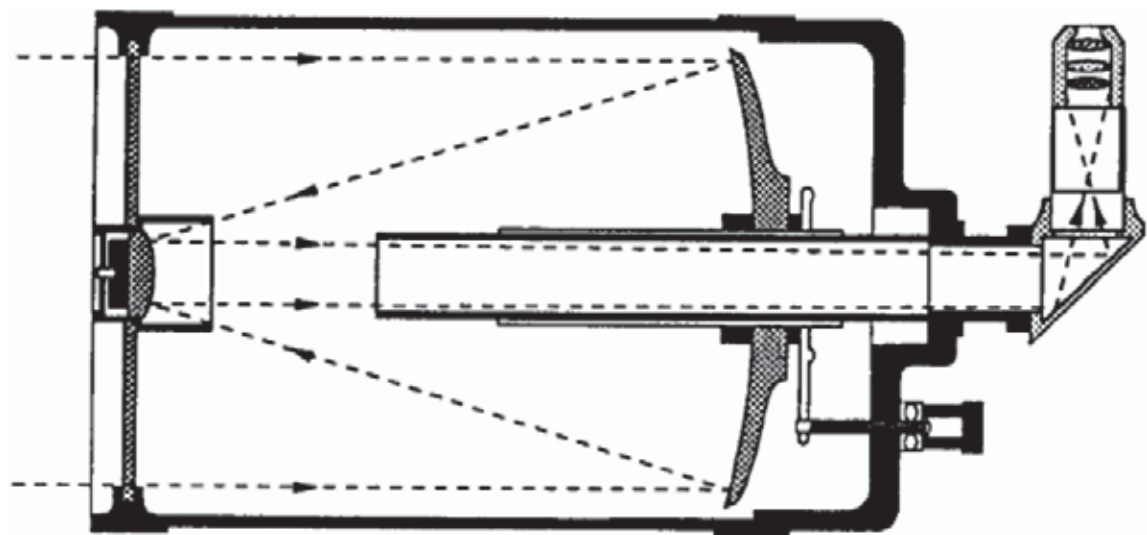


Figure B-2 Celestron SCT

Note. From Celestron®, 2006, *CPC™ Series Instructional Manual*. Copyright 2006 by Celestron, Torrance, CA: Celestron.

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**ROYAL CANADIAN AIR CADETS  
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**SECTION 10**

**EO C440.08 – WATCH *BLAST!* (BALLOON-BORNE  
LARGE APERTURE SUB-MILLIMETRE TELESCOPE)**

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Total Time: 90 min

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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Create slides of the figures located at Attachments A and B.

Photocopy Attachment C for each cadet.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for TP 1 to introduce the cadets to cosmology and give an overview of the BLAST mission.

An in-class activity was chosen for TP 2 as it is an interactive way to reinforce cosmology, provoke thought and stimulate interest among cadets.

A group discussion was chosen for TP 3 as it allows the cadets to interact with their peers and share their knowledge, experiences, opinions, and feelings about cosmology using a balloon-borne large aperture sub-millimetre telescope.

---

**INTRODUCTION**

---

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to discuss the professional challenges that astrophysicists faced in the BLAST mission.



**IMPORTANCE**

It is important for cadets to discuss the professional challenges that astrophysicists face so that they understand how astrophysics is influenced by aerospace technologies.

**Teaching Point 1****Describe the BLAST mission.**

Time: 10 min

Method: Interactive Lecture



The word sub-millimetre, as it is used in this lesson, refers to the proximate wavelength of near-infrared electromagnetic energy, which can be thought of as the warmth of the sun. Most animals see the sun at visible wavelengths but they feel the sun in the far-infrared. Sub-millimetre near-infrared energy is blocked by atmospheric water vapour.

**OBSERVATION OF STAR FORMATION**

Astrophysicists are interested in learning more about how the earliest galaxies and stars were formed. However, these objects are often hidden by gas and dust so they cannot be seen in visible light. Fortunately, star births are fiery events. Heat from the newborn stars warms the surrounding dust, which then emits sub-millimetre radiation—a form of infrared electromagnetic radiation close to visible light. Infrared radiation, having wavelengths that are longer than visible light, can pass through dusty regions of space without being scattered. In order to detect much of this radiation, however, sub-millimetre telescopes must be built.

Water vapour in the Earth's atmosphere absorbs radiation across large parts of the infrared and sub-millimetre wavebands, making ground-based observations at some of these wavelengths impossible. Limited observations can be made from high-altitude balloons, such as BLAST, but space-based observatories such as the European Space Agency's Herschel are the only truly satisfactory solution to this problem.



Show the cadets the slide of Figure A-1 located at Attachment A.

**OBSERVATION OF GALAXY FORMATION**

When astronomers look further out into space, they are actually looking further back in time. Light travels incredibly fast and seems instantaneous at short distances on the Earth, but light from distant galaxies takes millions or even billions of years to reach Earth. The further out one looks into space, the longer that light has travelled. Observers are literally seeing the light of events that happened in the remote past. Looking further and further back, astronomers can develop a timeline for the evolution of the universe.



Show the cadets the slide of Figure A-2 located at Attachment A.



Learn more about infrared astronomy in The Cosmic Classroom: The Infrared Universe at <http://coolcosmos.ipac.caltech.edu/>

## THE BLAST MISSION DESIGN



Key words:

**Bolometers.** The sensors that detect sub-millimetre light.

**Gondola.** The large metal structure that holds the telescope, motors, and computers.

**Payload.** Anything dangling from the balloon.

**Star cameras.** Cameras that BLAST uses to orient itself in the sky.

Large unmanned helium balloons have long provided NASA with an inexpensive means to place payloads into a near-space environment. The unique capabilities of this program are crucial for the development of new technologies and payloads for NASA's space flight missions. They also offer essential training for the next generation of scientists, as can be seen in *BLAST!* As well, many important scientific observations are made from long-duration balloon flights.

BLAST used the Sun's energy to power instruments and took advantage of the Sun's continuous presence during the summers at the North and South Poles. Flying only in constant daylight, BLAST was ensured a steady source of power and a flight at a stable altitude. If the Sun were to set during the flight, the helium in a balloon would cool and it would drop to a lower altitude. At sunrise, the helium would heat and the balloon would rise.

BLAST needed a way to orient itself and point the telescope in the right direction. Although it had an onboard Global Positioning System (GPS), BLAST relied on the stars for its navigation. On top of the main mirror are two star cameras (long white tubes). These cameras took pictures of stars whose positions in the sky are well known. BLAST's computers then analyzed these reference points and, through a series of motors and gyroscopes, adjusted its orientation accordingly.

When landing, a remote-controlled system separated BLAST from the balloon and a parachute opened to help slow the telescope's descent. It took about 45 minutes for BLAST to reach the ground. The parachute was designed to then detach itself from the gondola. The precious hard drive, containing all of the data, had to be physically recovered. Recovery could be very difficult, depending on where BLAST landed.

In 2005, BLAST flew from Sweden to Canada while making moderately successful observations.



Show the cadets the slide of Figure B-1 located at Attachment B.

In 2006, BLAST flew over Antarctica while making very successful observations.



Show the cadets the slide of Figure B-2 located at Attachment B.

---

**CONFIRMATION OF TEACHING POINT 1****QUESTIONS:**

- Q1. Why are sub-millimetre telescopes, which observe infrared radiation, needed for studying star formation?
- Q2. Why must sub-millimetre telescopes operate in or near space?
- Q3. How long did it take BLAST to descend to the ground on its parachute?

**ANTICIPATED ANSWERS:**

- A1. Infrared radiation has wavelengths that are much longer than visible light, so it can pass through the dusty regions of space where stars are formed without being scattered.
- A2. Water vapour in the Earth's atmosphere absorbs radiation across large parts of the infrared and sub-millimetre wavebands, making ground-based observations at some of these wavelengths impossible.
- A3. It took about 45 minutes for BLAST to reach the ground.

---

**Teaching Point 2****Have the cadets watch *BLAST!***

Time: 55 min

Method: In-Class Activity

---

**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets watch the 53-minute motion picture *BLAST! (Balloon-Borne Large Aperture Sub-Millimetre Telescope)*.

**RESOURCES**

- *BLAST!* DVD, and
- Handout of Attachment C.

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Distribute Attachment C to each cadet.
2. Instruct the cadets to consider the questions posed on the handout while watching *BLAST!*
3. Play the entire 53-minute motion picture *BLAST! (Balloon-Borne Large Aperture Sub-Millimetre Telescope)*.

**SAFETY**

Nil.

---

## CONFIRMATION OF TEACHING POINT 2

The cadets' participation in the activity will serve as the confirmation of this TP.

---

### Teaching Point 3

**Discuss the science and the design of the BLAST mission.**

Time: 15 min

Method: Group Discussion

---

## BACKGROUND KNOWLEDGE

---



The point of the group discussion is to draw the following information from the group using the tips for answering / facilitating discussion and the suggested questions provided.

The background knowledge for this discussion is to be based on TP 1 and the material in the motion picture *BLAST! (Balloon-Borne Large Aperture Sub-Millimetre Telescope)*.

---

## GROUP DISCUSSION

---



### TIPS FOR ANSWERING / FACILITATING DISCUSSION:

- Establish ground rules for discussion, eg, everyone should listen respectfully; don't interrupt; only one person speaks at a time; no one's ideas should be made fun of; you can disagree with ideas but not with the person; try to understand others as much as you hope they understand you; etc.
- Sit the group in a circle, making sure all cadets can be seen by everyone else.
- Ask questions that will provoke thought; in other words avoid questions with yes or no answers.
- Manage time by ensuring the cadets stay on topic.
- Listen and respond in a way that indicates you have heard and understood the cadet. This can be done by paraphrasing their ideas.
- Give the cadets time to respond to your questions.
- Ensure every cadet has an opportunity to participate. One option is to go around the group and have each cadet answer the question with a short answer. Cadets must also have the option to pass if they wish.
- Additional questions should be prepared ahead of time.

**SUGGESTED QUESTIONS:**

- Q1. What are the main features of the professional relationship between the graduate student responsible for the Star Cameras and her two professors?
- Q2. Other than geography, what important similarities and links are there between Shackleton's missions and the BLAST mission?
- Q3. Why is it so important for visitors to McMurdo Station to be physically qualified (PQ)?
- Q4. How might a better understanding of the early universe affect everyday life?



Other questions and answers will develop throughout the group discussion. The group discussion should not be limited to only those suggested.



Reinforce those answers given and comments made during the group discussion, ensuring the teaching point has been covered.

**CONFIRMATION OF TEACHING POINT 3**

The cadets' participation in the group discussion will serve as the confirmation of this TP.

**END OF LESSON CONFIRMATION**

The cadets' participation in watching and discussing *BLAST!* will serve as the confirmation of this lesson.

**CONCLUSION****HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

Astrophysicists face daunting challenges while pushing back the frontiers of science. Fortunately, the tools and the constant development of aerospace technologies allow scientific research to progress.

**INSTRUCTOR NOTES / REMARKS**

It is recommended that this EO be presented in three consecutive periods.

If EO C440.07 (Operate a Telescope) is selected, it is recommended that it be presented prior to this lesson.

---

**REFERENCES**

---

C3-295 Devlin, P. (Producer & Director). (2008). *BLAST!* [Motion picture]. United States: The ArtistShare Project.

C3-298 *BLAST (Balloon-Borne Large Aperture Sub-Millimetre Telescope)*. University of Pennsylvania Department of Physics and Astronomy. Retrieved January 30, 2009, from <http://blastexperiment.info/>



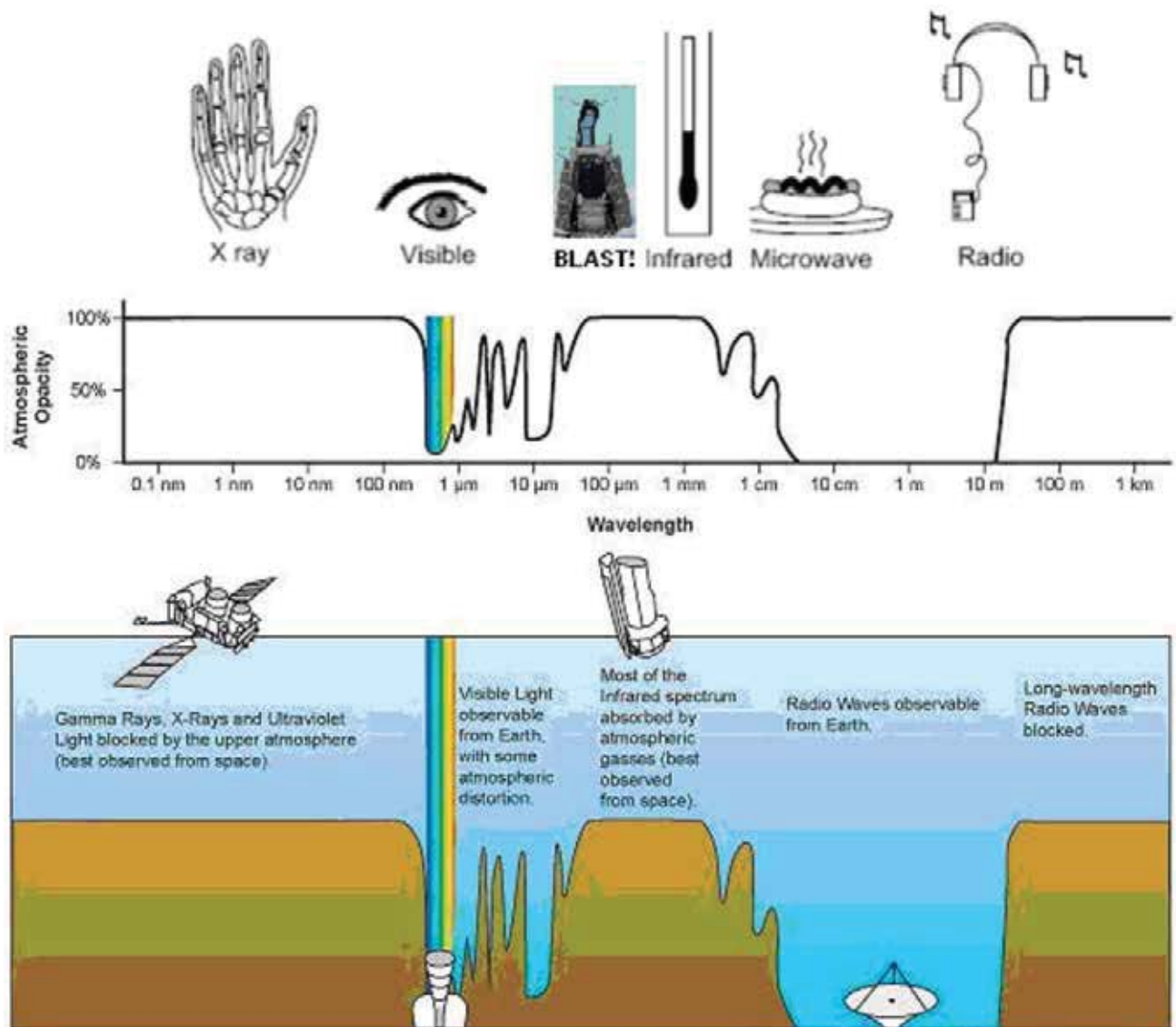


Figure A-1 The Electromagnetic Spectrum and Atmospheric Opacity

Note. From "Infrared Windows", *The Cosmic Classroom*, by California Institute of Technology, 2009. Retrieved March 27, 2009, from <http://www.ipac.caltech.edu/Outreach/Edu/Windows/irwindows.html>

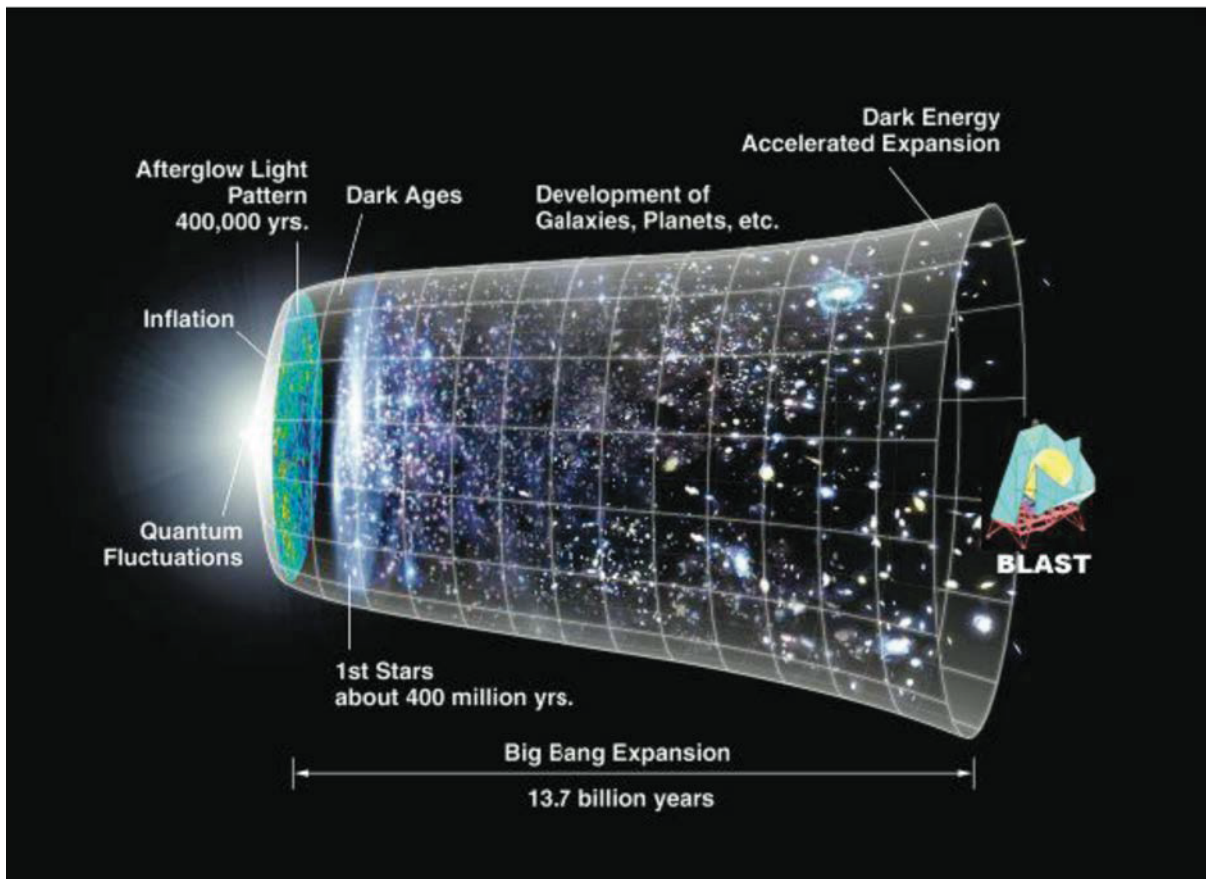


Figure A-2 The Big Bang

Note. From "BLAST: How It Works", *The Importance of BLAST*, by the ArtistShare Project, 2009. Retrieved March 28, 2009, from [http://www.blastthemovie.com/press/BLAST\\_HowItWorks.pdf](http://www.blastthemovie.com/press/BLAST_HowItWorks.pdf)

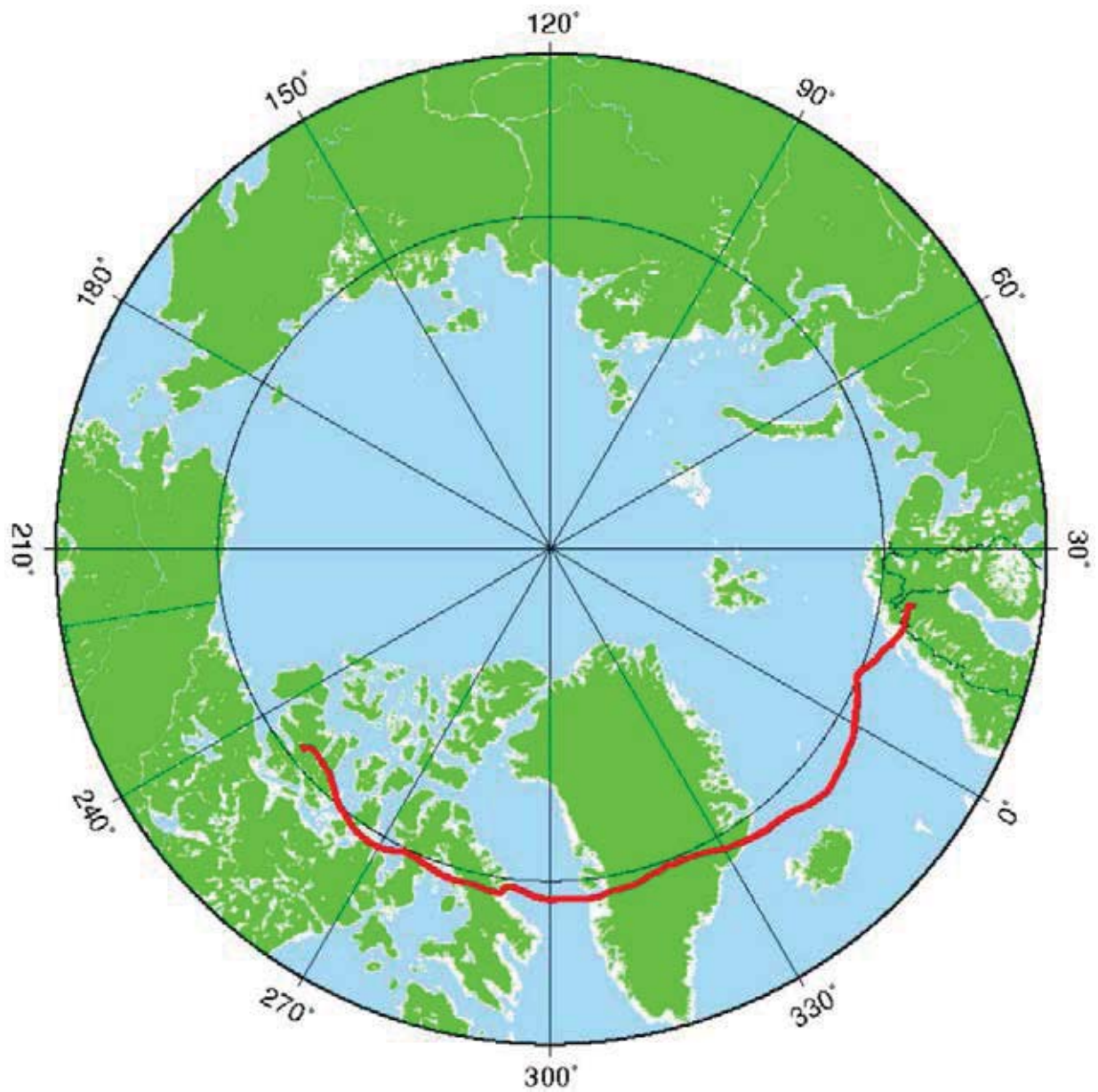


Figure B-1 BLAST Path 2005

*Note.* From "Flight Trajectory", *BLAST*, by Swedish Space Corporation, 2009. Retrieved March 28, 2009, from <http://www.ssc.se/?id=7082>

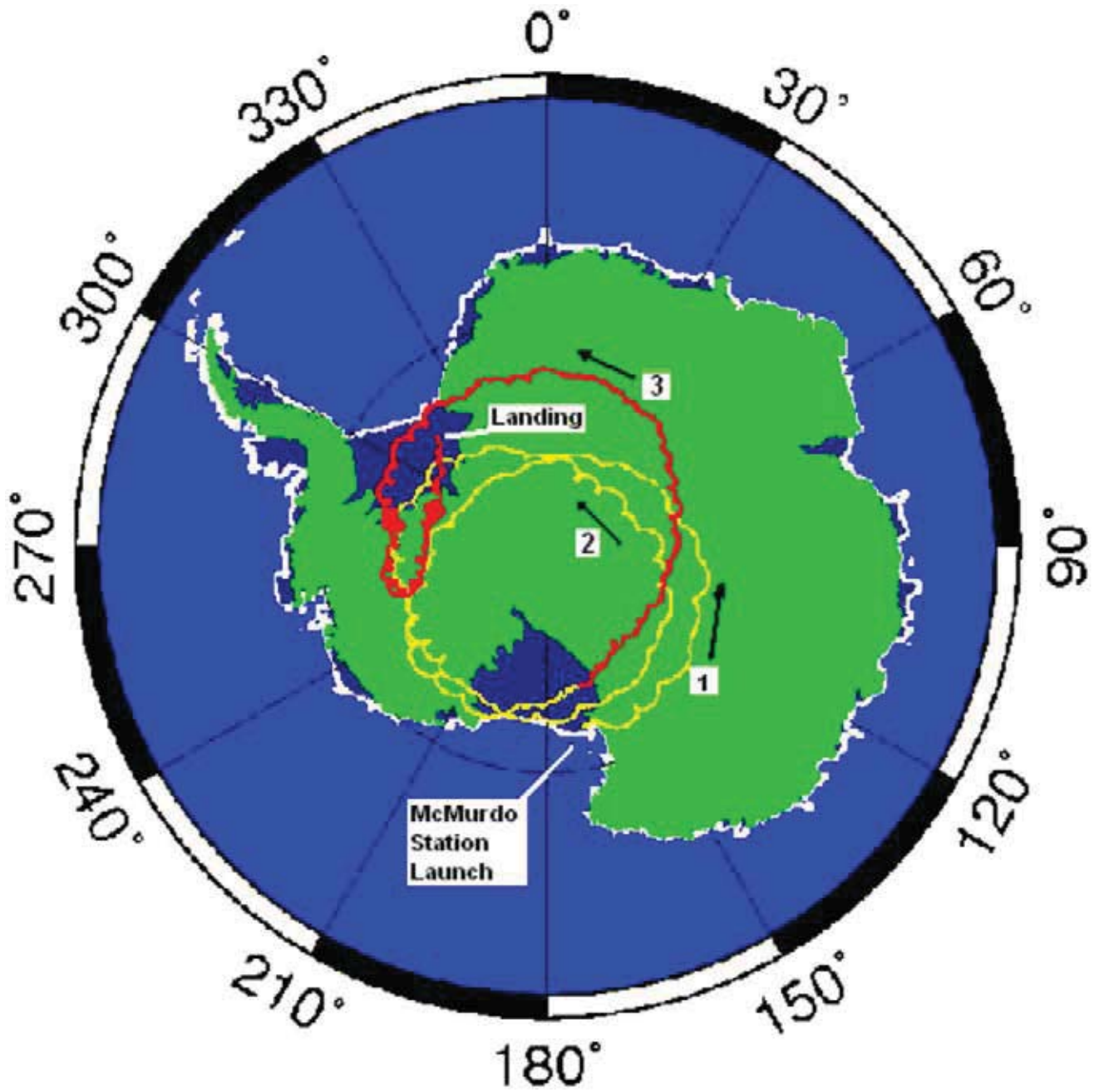


Figure B-2 BLAST Path 2006

Note. From "Flight Trajectory", *BLAST*, by Swedish Space Corporation, 2009.  
Retrieved March 28, 2009, from <http://www.nsf.nasa.gov/map/balloon4/balloon4.png>

**QUESTIONS TO CONSIDER WHILE WATCHING *BLAST!***

- What advantages are there in doing balloon missions during the Arctic and Antarctic summers?
- What is the nature of the professional relationship between graduate students and professors?
- Why do scientists attach great importance to priority—being the first to publish new knowledge?
- How might the European Space Agency's Herschel space telescope benefit from a balloon-based test of its cutting-edge infrared bolometers?
- Why do countries such as Canada and institutions such as York University see great value in this expensive pure science, which concerns events that happened billions of light-years away and billions of years ago?

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**ROYAL CANADIAN AIR CADETS**  
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**SECTION 11**

**EO C440.09 – DESCRIBE THE RELATIONSHIP BETWEEN GRAVITY AND SPACE-TIME**

Total Time:

60 min

**PREPARATION**

**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Obtain and cue the following six Windows Media Video (WMV) files from Reference C3-312 located at <http://einstein.stanford.edu/index.html>

- WMV file *Newtons\_Universe\_Anima*,
- WMV file *Einsteins\_Universe\_Anima*,
- WMV file *Rel\_gyro\_expt-anima*,
- WMV file *SConSquid*,
- WMV file *Simple\_expt\_anima*, and
- WMV file *DF-Satellite*.

Create slides of figures located at Attachment A.

Photocopy the Gravity and Space-Time handout located at Attachment B for each cadet.

Obtain a copy of Reference C3-310, *Gravity Probe B: An Educator's Guide*.

Obtain and cue the *Testing Einstein's Universe* DVD.

Obtain a large round coin, such as a Canadian two-dollar piece, for use in TP 2.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An interactive lecture was chosen for TPs 1 and 2 to introduce theories of gravitation and give an overview of the Gravity Probe B mission.



An in-class activity was chosen for TPs 3 and 4 as it as it is an interactive way to reinforce the relationship between gravity and space-time, provoke thought, and stimulate interest among cadets.

---

## INTRODUCTION

---

### REVIEW

Nil.

### OBJECTIVES

By the end of this lesson the cadet shall be expected to describe the relationship between gravity and space-time.

### IMPORTANCE

It is important for cadets to describe the relationship between gravity and space-time because viewing gravity as a curvature of space-time explains more phenomena in the aerospace environment than the classical Newtonian view of gravity as a force of attraction.

**Teaching Point 1****Compare early ideas of gravity to gravitation under the theory of relativity.**

Time: 10 min

Method: Interactive Lecture

**NEWTON'S UNIVERSAL LAW OF GRAVITATION**

Show the cadets the WMV file *Newtons\_Universe\_Anima*.  
Running time is 1 minute, 8 seconds.

**GRAVITY AS A FORCE BETWEEN MASSES**

According to Newton's theory of gravity, all bodies possess the force of attraction called gravity. Larger masses, such as the Sun, attract smaller masses, such as the planets and comets, more strongly, causing the smaller masses to move toward the larger masses. In our solar system, the planets orbit the Sun due to the force of the Sun's gravity pulling them into this elliptical path. Comets soaring through the galaxy are curved toward the Sun due to gravity's pull.

**INSTANTANEOUS TRANSMISSION OF GRAVITY**

In *Principia* (1687), Newton stated, "there is a power of gravity pertaining to all bodies, proportional to the several quantities of matter which they contain." However, when Newton was questioned about how this "power of gravity" transmitted from one body to another, he responded, "I make no hypothesis."

Einstein, along with other scientists, began to question this conclusion around the turn of the 20<sup>th</sup> century. In the 19<sup>th</sup> century, Maxwell had shown that light propagated at a finite rate in a vacuum; 299 792 km / sec (185 871 miles / sec). In 1905, Einstein's theory of special relativity was based on the idea that this rate was the speed limit for all matter and energy in the universe. If gravity was a force that transmitted between masses in the same way light propagated through space, the force of gravity should be equally restricted to 299 792 km / sec. While moving nearly 300 000 km each second is extremely fast, it is not instantaneous.

**THE INTERDEPENDENCE OF SPACE AND TIME**

Newton believed that space and time were absolute or fixed entities and that gravity could be represented as an attractive force that somehow acted instantaneously between objects. Einstein determined that space and time are relative entities, interwoven into a "fabric," which he called space-time, and he realized that no force—not even gravity—could act faster than the speed of light. In Einstein's universe, the presence of celestial bodies causes space-time to warp or curve; and gravity is not a force, but rather the product of bodies moving in curved space-time.

Since space and time were separate concepts in Newton's physics, an object's position is simply described by three spatial coordinates. In Einstein's physics, space and time are combined into space-time so that when describing the position of an object one must include all four dimensions—the three spatial dimensions and time. The passage of time is relative to motion, so the time coordinate in the description of position describes time relative to a frame of reference, which is absolutely critical in Einstein's relativity.

## CURVATURE OF SPACE-TIME



Show the cadets the WMV video file *Einsteins\_Universe\_Anima*.  
Running time is 1 minute, 9 seconds.

In 1916, Einstein presented the world with this new understanding of the universe—his general theory of relativity. In his theory, space is not an empty void, but an invisible structure called space-time. Nor is space simply a three-dimensional grid through which matter and light and energy move. It is a four-dimensional structure called space-time whose shape is curved and twisted by the presence and motion of matter and energy.

Space-time curves around any mass. The presence of planets, stars and galaxies warps the fabric of space-time in a manner similar to a bowling ball warping a spandex sheet. The mass of the ball stretches the fabric and creates a dip or curve that gradually decreases the further one moves from the mass.

When a mass passes near a larger mass, it accelerates toward the larger mass because space-time itself is curved toward the larger mass. The smaller mass is not “attracted” to the larger mass by any force. The smaller mass simply follows the structure of curved space-time near the larger mass. For example, the massive Sun curves space-time around it, a curvature that reaches out to the edges of the solar system and beyond. The planets orbiting the Sun are following the curvature of space-time by the Sun.



Show the cadets the WMV file *Rel\_gyro\_expt-anima*.  
Running time is 3 minutes, 1 second.

---

## CONFIRMATION OF TEACHING POINT 1

### QUESTIONS:

- Q1. What was the speed limit for all matter and energy in the universe under Einstein's 1905 Special Theory of Relativity?
- Q2. How many coordinates describe an object's position in Newton's physics?
- Q3. How many coordinates describe an object's position in Einstein's physics?

### ANTICIPATED ANSWERS:

- A1. The speed of light propagating at a finite rate in a vacuum: 299 792 km / sec (185 871 miles / sec).
- A2. In Newton's physics, an object's position is simply described by three spatial coordinates.
- A3. In Einstein's physics, space and time are combined into space-time so that when describing the position of an object one must include all four dimensions—the three spatial dimensions and time.

**Teaching Point 2****Describe the Gravity Probe B (GP-B) mission.**

Time: 10 min

Method: Interactive Lecture

**GYROSCOPE OPERATION**

The gyroscope is a spinning wheel (rotor) in a universal mounting (gimbal) that allows its axle to be pointed in any direction.

Also known as rigidity in space, gyroscopic inertia is the tendency of a rotating object to remain in its plane of rotation. This allows the spin axis of a gyroscope to remain unchanged regardless of how the gimbal is moved around it.



Show the cadets the slide of Figure A-1 located at Attachment A.

Examples of rotating objects that exhibit rigidity in space are tops, gyroscopes, Frisbees, basketballs and any spinning planet. These objects tend to maintain their orientation in space.



Aircraft use gyroscopes for navigation, with the gyroscope maintaining the orientation of the universe so that relative changes in the aircraft's orientation can be measured. In the Gravity Probe B (GP-B) satellite, the gyroscope maintains its orientation relative to a distant guide star so that the changes in the orientation of space-time near Earth can be measured.

To work properly, the rotor must be kept spinning at a constant speed. Gyroscopic instruments may be powered by one or more power sources. In an aircraft, a gyroscope can be powered by moving air systems. In the GP-B satellite, the gyroscopes are powered by helium gas that is stored as liquid in the largest satellite component: the dewar.



**Dewar.** A double-walled vessel with a vacuum between the walls to reduce the transfer of heat, used for storing hot or cold liquid.



Show the cadets the slide of Figure A-2 located at Attachment A.

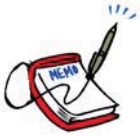
**THE SPIN AXIS OF A GYROSCOPE**

Spin a coin on its edge to show the cadets that it will remain upright while spinning. Demonstrate that the coin will not remain upright on its edge when it is not spinning.

It was predicted that the spin axis of each of GP-B's four gyroscopes move with the curvature and twist of local space-time around Earth. The only way this motion can be detected is by comparing each spin axis to a fixed line of reference. In this mission, the fixed reference line is the line between the telescope and the guide star: IM Pegasi. The telescope has to remain fixed on the exact centre of the guide star (within one milliarsecond, or 1 millionth of an inch) throughout the mission or GP-B would lose its single critical reference line.



**SQUID (Superconducting QUantum Interference Device).** A device that monitors the spin axis orientation of the supercooled, superconducting gyroscope's perfectly unmarked, spherical rotor—without exerting significant torque on the spinning rotor.



Show the cadets the WMV video file *SConSquid*.  
Running time is 2 minutes, 12 seconds.

### GEODETIC EFFECT

Einstein's theory predicted that the presence of a mass in space, such as the Earth, will warp local space-time, creating a dip or curve in space-time. This is called geodetic effect.

### FRAME-DRAGGING EFFECT

One of the predictions of Einstein's general theory of relativity is that local space-time is twisted by the rotation of the Earth—any rotating mass will drag the local space-time frame of reference with it. The predicted drag is very small and fades as one travels further from the rotating mass, but the twist nearby can affect the paths of light, energy, and other masses.



Show the cadets the WMV video file *Simple\_expt\_anima*.  
Running time is 1 minute, 7 seconds.

### SPACECRAFT COMPONENTS

The GP-B satellite is composed of thousands of components, but the mission can be understood by considering only a few, to include:

- dewar,
- gyroscopes,
- star tracking telescope, and
- micro thrusters.



Show the cadets the WMV video file *DF-Satellite*.  
Running time is 4 minutes 25 seconds.

## CANADA'S CONTRIBUTION TO ORIENTATION CONTROL

Astrophysicists at York University measured and tracked the movement of GP-B's guide star, IM Pegasi, against a backdrop of more distant quasars. This allowed minute changes in the position of IM Pegasi to be taken into account when changes in gyroscope orientation was measured—in a system where angles of a millionth of a degree are of critical importance.



**Quasar.** Any of a class of starlike celestial objects, apparently of great size and remoteness, often associated with a spectrum with a large red shift and intense radio emission.

---

### CONFIRMATION OF TEACHING POINT 2

#### QUESTIONS:

- Q1. What is meant by rigidity in space?
- Q2. What is geodetic effect?
- Q3. What is frame-dragging effect?

#### ANTICIPATED ANSWERS:

- A1. Rigidity in space is the tendency of a rotating object to remain in its plane of rotation.
- A2. One of the predictions of Einstein's theory; the presence of a mass in space, such as the Earth, will warp local space-time, creating a dip or curve in space-time.
- A3. One of the predictions of Einstein's general theory of relativity; local space-time is twisted by the rotation of the Earth.

---

### Teaching Point 3

**Have the cadets watch *Testing Einstein's Universe*.**

Time: 25 min

Method: In-Class Activity

---

### ACTIVITY

#### OBJECTIVE

The objective of this activity is to have the cadets learn about the GP-B mission by watching *Testing Einstein's Universe* while finding answers to assigned questions.

#### RESOURCES

- Testing Einstein's Universe DVD,
- Gravity and Space-Time handout located at Attachment B for each cadet,
- Paper, and
- Pens / pencils.

## ACTIVITY LAYOUT

Nil.

## ACTIVITY INSTRUCTIONS

1. Distribute the Gravity and Space-Time handout located at Attachment B to each cadet.
2. Instruct the cadets to record their answers to the questions in the Gravity and Space-Time handout while watching *Testing Einstein's Universe*.
3. Have the cadets watch *Testing Einstein's Universe*.

## SAFETY

Nil.

---

## CONFIRMATION OF TEACHING POINT 3

The cadets' participation in the activity will serve as the confirmation of this TP.

---

## Teaching Point 4

**Conduct an activity to correct answers to the assigned questions.**

Time: 5 min

Method: In-Class Activity

---

## ACTIVITY

### OBJECTIVE

The objective of this activity is to have the cadets check their answers to the questions at Attachment B.

### RESOURCES

- Reference C3-310, *Gravity Probe B: An Educator's Guide*,
- Answer Key—Gravity And Space-Time located at Attachment C, and
- Completed Gravity and Space-Time handouts.

## ACTIVITY LAYOUT

Nil.

## ACTIVITY INSTRUCTIONS

1. Using the answer key located at Attachment C, read the answer to the question.
2. Have the cadets confirm their answer. If required, discuss any discrepancies, referring to Reference C3-310 as necessary.
3. Repeat Steps 1 and 2 for each question.

## SAFETY

Nil.



---

**CONFIRMATION OF TEACHING POINT 4**

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**END OF LESSON CONFIRMATION**

The cadets' participation in watching *Testing Einstein's Universe* will serve as the confirmation of this lesson.

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**CONCLUSION**

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**HOMEWORK / READING / PRACTICE**

Nil.

**METHOD OF EVALUATION**

Nil.

**CLOSING STATEMENT**

The relationship between gravity and space-time is still theoretical. However, the relativistic theory of gravity as a manifestation of the curvature of space accounts for more natural phenomena than the classical Newtonian explanation.

**INSTRUCTOR NOTES / REMARKS**

Nil.

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**REFERENCES**

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C3-310 Range, S. K. (2004). *Gravity Probe B: An educator's guide*. Washington, DC: NASA. Retrieved February 6, 2009, from <http://einstein.stanford.edu/RESOURCES/education-index.html#guide>

C3-311 Bartel, N. (Producer & Director). (2003). *Testing Einstein's universe* [Motion picture]. Canada: York University.

C3-312 Range, S. K. (2008). *Gravity Probe B: Testing Einstein's universe*. Retrieved February 6, 2009, from <http://einstein.stanford.edu/index.html>

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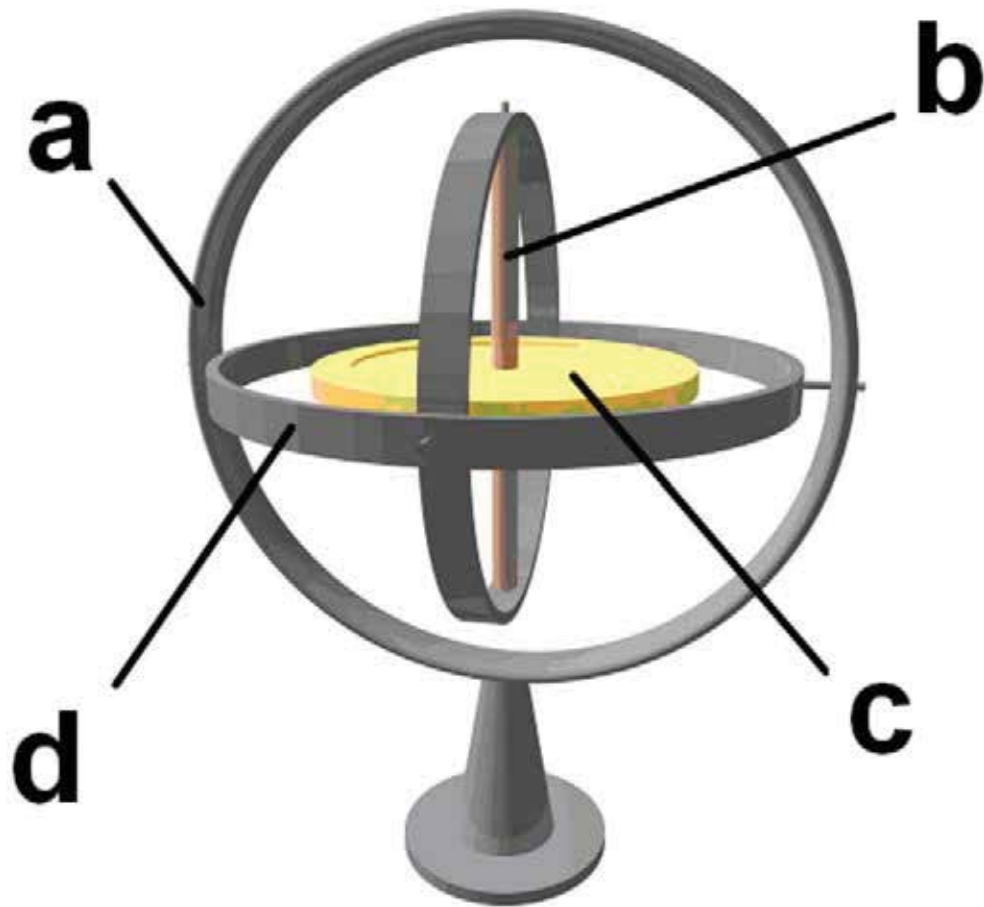


Figure A-1 Gyroscope

*Note.* From "3D Gyroscope", *Wikimedia*. Retrieved November 18, 2008, from [http://upload.wikimedia.org/wikipedia/commons/e/e2/3D\\_Gyroscope.png](http://upload.wikimedia.org/wikipedia/commons/e/e2/3D_Gyroscope.png)

- a. Gyroscope frame
- b. Spin axis
- c. Rotor
- d. Gimbal



Figure A-2 Gravity Probe B Dewar

*Note.* From *Gravity Probe B: An Educator's Guide*, (p. 30), by S. Shannon, 2004. Washington, DC: NASA.

**GRAVITY, SPACE-TIME AND GP-B**

Q1. Name two 20<sup>th</sup> century tests of Einstein's general theory of relativity.

- \_\_\_\_\_
- \_\_\_\_\_

Q2. Why was Gravity Probe B placed into a low orbit even though that meant it would be buffeted by the upper atmosphere?

---

---

Q3. Why was Gravity Probe B placed into a polar orbit?

---

---

Q4. What were three uses of the liquid helium in Gravity Probe B's dewar?

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

Q5. In Einstein's Equivalence Principle, what is said to be equivalent?

---

---

Q6. What is the significance of Gravity Probe B's drag-free status?

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**ANSWER KEY—GRAVITY, SPACE-TIME AND GP-B**

- Q1. Name two 20<sup>th</sup> Century tests of Einstein's general theory of relativity.
- A1. Reference C3-310 (pp. 13–14): Any two of:
- precession of Mercury's orbit,
  - starlight deflection during a solar eclipse,
  - gravitational redshift, and
  - shapiro time delay.
- Q2. Why was Gravity Probe B placed into a low orbit even though that meant it would be buffeted by the upper atmosphere?
- A2. Reference C3-310 (p. 32): The effects of local space-time (its curve and twist) weaken dramatically as one moves farther from the Earth. Gravity Probe B was given an orbit that would get it as close to the Earth as possible, to see the space-time effects more clearly.
- Q3. Why was Gravity Probe B placed into a polar orbit?
- A3. WMV file *Rel\_gyro\_expt-anima*: In a polar orbit the two effects, geodetic and frame-dragging, occur at right angles, providing maximum separation. This makes it possible for a gyroscope to measure both effects simultaneously.
- Q4. What were three uses of the liquid helium in Gravity Probe B's dewar?
- A4. Three uses of the helium in Gravity Probe B's dewar include:
- Reference C3-310 (p. 25): Spinning the gyroscopes,
  - Reference C3-310 (p. 30): Supercooling the instruments, and
  - Reference C3-310 (p. 32): Powering the micro-thrusters.
- Q5. In Einstein's equivalence principle, what is said to be equivalent?
- A5. Reference C3-310 (p. 25): An experience of gravity is equivalent to an experience of acceleration.
- Q6. What is the significance of Gravity Probe B's drag-free status?
- A6. Reference C3-310 (p. 29): The slightest amount of heat or pressure, the influence of a magnetic field, any kind of gravitational acceleration, or the tiniest amount of atmospheric turbulence will destroy the accuracy of the instrument.



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**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 12**

**EO C440.10 – DISCUSS KINETIC AND POTENTIAL ENERGY**

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Total Time:	30 min
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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy Attachment A for each group of four cadets for TP 3.

Gather materials needed for the activities in TPs 1–3.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An in-class activity was chosen for this lesson as it is an interactive way to provoke thought about energy and stimulate interest in kinetic and potential energy among cadets.

---

**INTRODUCTION**

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**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to discuss kinetic and potential energy.

**IMPORTANCE**

It is important for cadets to understand the relationship between kinetic and potential energy so that they can recognize the requirements, applications and effects of propulsion systems, especially in a microgravity environment.

---

**Teaching Point 1****Explore the storage and conversion of kinetic and potential energy in a gravitational system.**

Time: 5 min

Method: In-Class Activity

---

**Kinetic energy.** Energy of motion. A falling yo-yo has kinetic energy.

**Potential energy.** Energy that is stored in an object. A yo-yo held above the floor has potential energy because gravity pulls it down.

Kinetic energy can be converted into potential energy and potential energy can be converted back into kinetic energy. This can be seen in the repeated actions of a yo-yo as it goes through its cycles.

Before the yo-yo begins its fall, it has stored energy due to its position above the floor. At the top of its cycle it has its maximum potential energy. As it starts to fall the potential energy begins to be changed into the kinetic energy of falling—but the string, being wound around the yo-yo spindle, converts the kinetic energy of falling into kinetic energy of rotation.

At the bottom, the yo-yo's potential energy has been converted into, first, kinetic energy of falling, which was then converted to rotation. The yo-yo will now have its maximum kinetic energy of rotation. When the string is tightly extended at the bottom of the yo-yo's cycle, its kinetic energy of rotation can be used, by a competent yo-yo operator, to wind the string back around the yo-yo's spindle. It helps to add energy to each cycle of the yo-yo by speeding it on its downward leg. This is necessary due to energy losses from friction.

---

**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets explore the storage and conversion of kinetic and potential energy in a gravitational system by operating a yo-yo.

**RESOURCES**

Yo-yo (one per cadet).

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Distribute a yo-yo to each cadet.
2. Explain the following rules of this competition:
  - a. Cadets shall stand to operate their yo-yos.
  - b. Yo-yos shall be operated vertically only.
  - c. Cadets shall return to their seats when their yo-yo stops.
  - d. The last cadet standing wins the competition.
3. Have the cadets prepare by winding the string around the yo-yo spindle.
4. On command, have the cadets begin cycling their yo-yo.

**SAFETY**

Cadets shall take care to not hit anyone or anything with their yo-yo.

**CONFIRMATION OF TEACHING POINT 1**

The cadets' participation in the yo-yo activity will serve as the confirmation of this TP.

**Teaching Point 2**

**Explore the storage and conversion of kinetic and potential energy in an elastic system.**

Time: 5 min

Method: In-Class Activity



An elastic band flying through the air has kinetic energy.

When an elastic band is stretched, it gains potential energy. As the elastic band is released, stored potential energy is changed to the kinetic energy of motion.

**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets explore the storage and conversion of kinetic and potential energy in an elastic system by using elastic bands in a target competition.

**RESOURCES**

Elastic bands (two different colours).

**ACTIVITY LAYOUT**

1. Clear an area at least 3 m on each side of a 2-m line on the floor.
2. Place an empty waste paper basket 3 m from the line.

**ACTIVITY INSTRUCTIONS**

1. Divide the cadets into two teams.
2. Give each team three elastic bands per cadet, with different colours for each team.
3. Have one member of each team advance to the line and attempt to shoot one elastic band into the waste paper basket by stretching and releasing it.
4. Have each cadet repeat Step 3 three times.
5. Declare the winner based on the team that has the most elastic bands in the waste paper basket.

**SAFETY**

Cadets shall not aim an elastic band at another person.

**CONFIRMATION OF TEACHING POINT 2**

The cadets' participation in the elastic band activity will serve as the confirmation of this TP.

**Teaching Point 3****Explore the effects of velocity and mass in the expenditure of energy.**

Time: 15 min

Method: In-Class Activity



This TP consists of making a series of craters of various sizes. Point out to the cadets the features of the craters they create as shown in Figure 1 (Lunar crater Aristarchus, 42 km in diameter, located west of Mare Imbrium).

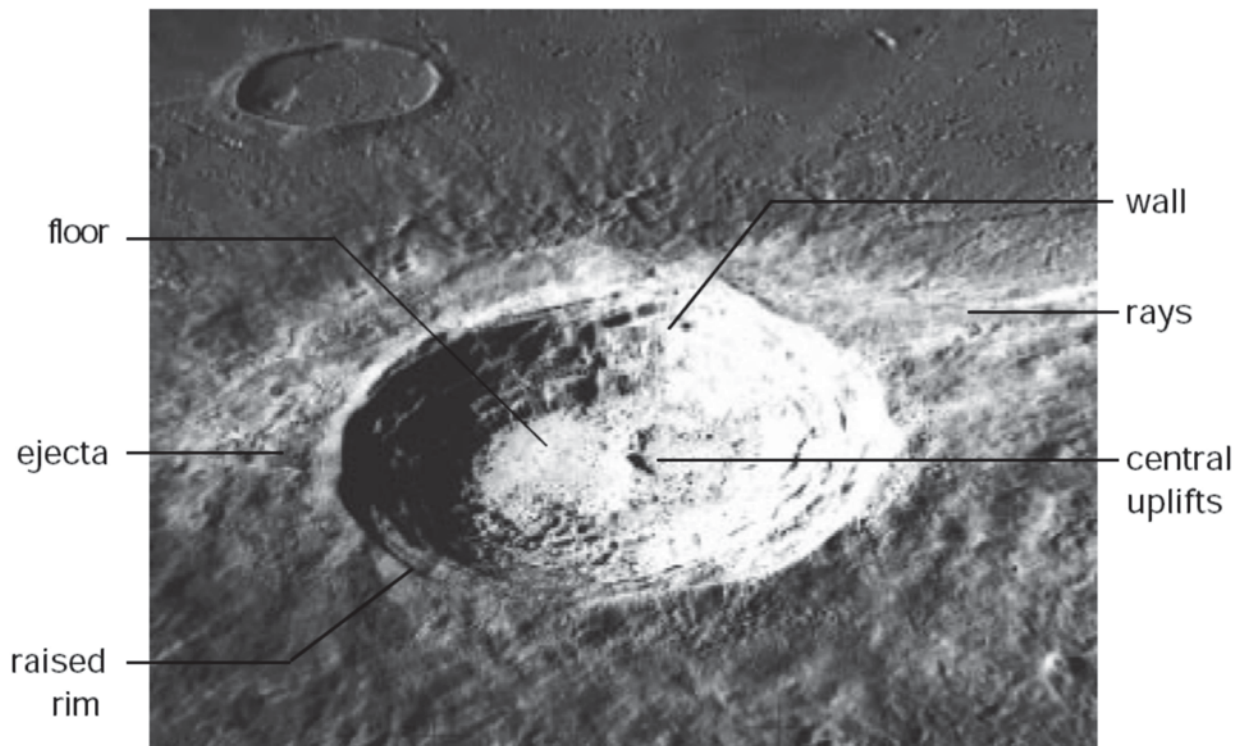


Figure 1 Parts of a Crater

*Note: From NASA, 1997, Exploring the Moon: A Teacher's Guide With Activities.*  
Retrieved September 30, 2008, from <http://lunar.arc.nasa.gov/education/pdf/expmoon.pdf>



The energy of a moving object is equal to its mass (weight) multiplied by the square of its velocity, or  $E = mv^2$ . An object travelling twice as fast will therefore deliver four times the energy at impact, and an object travelling three times as fast results in nine times the energy at impact.

**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets explore the effects of velocity and mass in the expenditure of energy through the creation of a series of craters.

## RESOURCES

- Impact Crater Data Chart located at Attachment A,
- Plastic tubs approximately 10 cm deep, 20 cm wide and 30 cm long,
- Ruler marked in millimetres,
- Sand (half tub),
- Cornstarch (half tub), and
- Impactors, to include:
  - marbles of various sizes,
  - ball bearings of various sizes,
  - wooden balls of various sizes, and
  - golf balls.

## ACTIVITY LAYOUT

1. Place a tub of mixed dry sand and cornstarch in the centre of an area that is clear at least 3 m on each side.
2. During this activity, the sand mixture may fall onto the floor and the cornstarch may even be dispersed into the air. Spread newspaper under the pan(s) to catch spills or conduct the activity outside.

## ACTIVITY INSTRUCTIONS

1. Divide the cadets into groups of no more than four.
2. Distribute one Impact Crater Data Chart located at Attachment A to each group.
3. Have the cadets drop impactors of various sizes into the tub of mixed sand and cornstarch from a height of 30 cm as per Attachment A.
4. Have the cadets measure the resulting craters and then select an effective impactor for the following exercise (an effective impactor will produce maximum rays, crater walls, a raised rim, and ejecta as shown in Figure 1, but it may not be possible to create a central uplift).
5. Have the cadets smooth and resurface the material in the pan before each impact. The material does not need to be packed down.



Shaking or tilting the pan back and forth produces a smooth surface. Better experimental control is achieved with consistent handling of the materials. For instance, cratering results may vary if the material is packed down for some trials and not for others.

6. Explain to the cadets that because of the low velocity of the experimental impactors compared with the velocity of real impactors, the experimental impact craters may not have significantly raised rims or central uplifts.
7. Have the cadets drop the impactor from increasing heights and record their data as per Attachment A.
8. Have the cadets analyze their results. They should observe that the higher drop height and resulting increase in velocity of the impactor creates a larger crater and spreads the ejecta out further.

## **SAFETY**

Nil.

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## **CONFIRMATION OF TEACHING POINT 3**

The cadets' participation in the crater activity will serve as the confirmation of this TP.

---

## **END OF LESSON CONFIRMATION**

The cadets' participation in exploring the storage and conversion of kinetic and potential energy in a gravitational system, the conversion of kinetic and potential energy in an elastic system, and the effects of velocity and mass in the expenditure of energy will serve as the confirmation of this lesson.

---

## **CONCLUSION**

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## **HOMEWORK / READING / PRACTICE**

Nil.

## **METHOD OF EVALUATION**

Nil.

## **CLOSING STATEMENT**

A coasting spaceship has kinetic energy that was gained from the potential energy stored in its fuel. A good understanding of the relationship between kinetic and potential energy helps to recognize the requirements, applications and effects of propulsion systems.

## **INSTRUCTOR NOTES / REMARKS**

Cadets who are qualified Advanced Aerospace may assist with this instruction.

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## **REFERENCES**

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C3-262 Canadian Space Agency. (2003). *Orbital mechanics: Energy*. Retrieved September 30, 2008, from <http://www.space.gc.ca/eng/educators/resources/orbital/energy.asp>

C3-263 EG-1997-10-116-HQ NASA. (1997). *Exploring the moon: A teacher's guide with activities*. Retrieved September 30, 2008, from <http://lunar.arc.nasa.gov/education/pdf/expmoon.pdf>

Name: \_\_\_\_\_

Date: \_\_\_\_\_

impactor #   
 gm

### Impact Craters - Data Chart

		trial 1	trial 2	trial 3	total	average
drop height = 30 cm velocity = 242 cm/s	crater diameter					
	crater depth					
	average length of all rays					
drop height = 60 cm velocity = 343 cm/s	crater diameter					
	crater depth					
	average length of all rays					
drop height = 90 cm velocity = 420 cm/s	crater diameter					
	crater depth					
	average length of all rays					
drop height = 2 m velocity = 626 cm/s	crater diameter					
	crater depth					
	average length of all rays					

Figure A-1 Impact Crater Data Chart

Note: From NASA, 1997, *Exploring the Moon: A Teacher's Guide With Activities*.  
 Retrieved September 30, 2008, from <http://lunar.arc.nasa.gov/education/pdf/expmoon.pdf>



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**ROYAL CANADIAN AIR CADETS  
PROFICIENCY LEVEL FOUR  
INSTRUCTIONAL GUIDE**



**SECTION 13**

**EO C440.11 – WATCH *EINSTEIN'S BIG IDEA***

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Total Time:	150 min
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**PREPARATION**

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**PRE-LESSON INSTRUCTIONS**

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Photocopy Attachment A for each cadet.

Photocopy the note template handout located at Attachment B.

Cue the DVD *Einstein's Big Idea*.

**PRE-LESSON ASSIGNMENT**

Nil.

**APPROACH**

An in-class activity was chosen for this lesson as it is an interactive way to provoke thought and stimulate interest among cadets about the development of the formula  $E=mc^2$ .

---

**INTRODUCTION**

---

**REVIEW**

Nil.

**OBJECTIVES**

By the end of this lesson the cadet shall be expected to discuss the history of the formula  $E=mc^2$ .

**IMPORTANCE**

It is important for cadets to be able to discuss the history of the formula  $E=mc^2$  so that they recognize that science is a team effort, which transcends both national boundaries and the centuries.

---

**Teaching Point 1**

**Conduct an activity where the cadets to define energy and describe kinds of energy and differences between sources of energy.**

Time: 5 min

Method: In-Class Activity

---



The term energy refers to the amount of work that can be performed by a system:

**Potential energy.** The energy an object has due to its position or condition.

**Kinetic energy.** The energy due to the motion of an object.

---

**ACTIVITY**

**OBJECTIVE**

The objective of this activity is to have the cadets brainstorm definitions of energy and to describe kinds of energy and differences between sources of energy.

**RESOURCES**

Nil.

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Have the cadets brainstorm definitions of energy.
2. Have the cadets list what kinds of energy they have used today.
3. Have the cadets list sources of energy (eg, sun, oil, natural gas, gasoline, wind, hydroelectric, nuclear, coal, wood, and food).
4. Point out that many of these are means of storing energy (eg, chemical storage such as natural gas) or forms of energy that are converted before becoming useful (eg, electrical energy converted to heat or mechanical energy).

**SAFETY**

Nil.

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**CONFIRMATION OF TEACHING POINT 1**

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**Teaching Point 2****Have the cadets determine that atoms of matter have mass.**

Time: 10 min

Method: In-Class Activity

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The nucleus of an atom is made up of protons and neutrons in a cluster. Virtually all the mass of the atom resides in the nucleus. The nucleus is held together by the tight pull of what is known to chemists and physicists as the "strong force". This force between the protons and neutrons overcomes the repulsive electrical force that would, according to the rules of electricity, otherwise push the positively-charged protons apart.

---

**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets determine that the atoms that constitute matter have mass.

**RESOURCES**

Handout located at Attachment A.

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Make a list of common materials on a flip chart or whiteboard, to include:
  - a. air,
  - b. water,
  - c. living organisms,
  - d. the sun, and
  - e. jewellery
2. Have the cadets identify the primary elements in air (nitrogen, oxygen), water (hydrogen, oxygen), living organisms (carbon, nitrogen, oxygen, hydrogen), the sun (hydrogen, helium), and jewellery (nickel, silver, gold).
3. Have the cadets locate those elements in a periodic table and determine their atomic mass.

**SAFETY**

Nil.

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**CONFIRMATION OF TEACHING POINT 2**

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**Teaching Point 3**

**Have the cadets watch *Einstein's Big Idea* and make notes on topics assigned.**

Time: 110 min

Method: In-Class Activity

---



Before watching *Einstein's Big Idea*, arrange for the cadets, singly or in groups, to make notes using the six handouts located at Attachment B.

The six note templates do not correspond to chapters in the motion picture. Information for the note templates will be found throughout the motion picture.

---

**ACTIVITY**

**OBJECTIVE**

The objective of this activity is to have the cadets take notes on their assigned topics while watching *Einstein's Big Idea*.

**RESOURCES**

- *Einstein's Big Idea* DVD,
- Note template handouts located at Attachment B, and
- Pens / pencils.

**ACTIVITY LAYOUT**

Nil.

**ACTIVITY INSTRUCTIONS**

1. Distribute the six note template handouts located at Attachment B. Each cadet should have one of the six note templates. If there are more than six cadets, they may form teams.
2. Ensure each template located at Attachment B has at least one cadet assigned to it.
3. Play *Einstein's Big Idea*.
4. Have the cadets, while watching *Einstein's Big Idea*, take notes on their assigned topics.

**SAFETY**

Nil.

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**CONFIRMATION OF TEACHING POINT 3**

The cadets' participation in the activity will serve as the confirmation of this TP.

---

**Teaching Point 4****Conduct an activity to create a timeline of the development of the formula  $E=mc^2$ .**

Time: 15 min

Method: In-Class Activity

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**ACTIVITY****OBJECTIVE**

The objective of this activity is to have the cadets construct a timeline showing the development of the formula  $E=mc^2$ .

**RESOURCES**

- String,
- Paper clips,
- Pens / pencils, and
- Completed note templates from TP 3.

**ACTIVITY LAYOUT**

Place a 3-m string across a classroom wall. Create a timeline ranging from 1700 to 1950 from the string by hanging paper century markers on the string with paper clips.

**ACTIVITY INSTRUCTIONS**

1. Have a cadet describe an assigned topic and the scientist's challenges and accomplishments.
2. Have the cadet clip the notes about that scientist to the appropriate place on the string.
3. Repeat for each scientist or team of scientists.
4. Draw the cadets' attention to the way that scientific research crossed national frontiers over very long periods of time. Point out that although historic contributors such as Socrates, Aristotle, Leonardo da Vinci and Sir Isaac Newton are not shown on this short timeline, their ideas were essential to the discoveries in *Einstein's Big Idea*.

**SAFETY**Nil.

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**CONFIRMATION OF TEACHING POINT 4**

The cadets' participation in the activity will serve as the confirmation of this TP.

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**END OF LESSON CONFIRMATION**

The cadets' participation in the timeline construction activity will serve as the confirmation of this lesson.

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## CONCLUSION

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### HOMEWORK / READING / PRACTICE

Nil.

### METHOD OF EVALUATION

Nil.

### CLOSING STATEMENT

Science is a team effort that transcends national boundaries and time. Our understanding of matter and energy are still very incomplete; while today we know more about light than Faraday and Maxwell, more about mass than the Lavoisiers and more about energy than du Châtelet, we have nevertheless scarcely begun. Science is teamwork in progress and it is not too late to join the team.

### INSTRUCTOR NOTES / REMARKS

If EO C440.09 (Describe the Relationship Between Gravity and Space-Time) or EO C440.10 (Discuss Kinetic and Potential Energy) are also selected, they should be presented prior to this lesson to introduce concepts of energy.

It is recommended that Chapters 1–6 of Einstein's Big Idea be presented in three consecutive periods and Chapters 7–9 be presented in two consecutive periods, all on two consecutive training days.

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## REFERENCES

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C3-319 NOVA. (2005). *Teacher's guide: Einstein's big idea*. Retrieved January 30, 2009 from <http://www.pbs.org/wgbh/nova/einstein/>

C3-320 Johnstone, G. (Producer & Director). (2005). *Einstein's big idea* [Motion picture]. United States: WBGH Educational Foundation.

**Table of Element Abbreviations and Names**

Ac	Actinium	Ha	Hahnium	P	Phosphorus
Ag	Silver	He	Helium	Pr	Praseodymium
Al	Aluminum	Hf	Hafnium	Pt	Platinum
Am	Americium	Hg	Mercury	Pu	Plutonium
Ar	Argon	H	Hydrogen	Ra	Radium
As	Arsenic	Ho	Holmium	Rb	Rubidium
At	Astatine	Hs	Hassium	Re	Rhenium
Au	Gold	I	Iodine	Rf	Rutherfordium
Ba	Barium	In	Indium	Rh	Rhodium
B	Boron	Ir	Iridium	Rn	Radon
Be	Beryllium	Kr	Krypton	Ru	Ruthenium
Bi	Bismuth	La	Lanthanum	Sb	Antimony
Bk	Berkelium	Li	Lithium	Sc	Scandium
Br	Bromine	Lr	Lawrencium	Se	Selenium
Ca	Calcium	Lu	Lutetium	Sg	Seaborgium
C	Carbon	Md	Mendelevium	Si	Silicon
Cd	Cadmium	Mg	Magnesium	Sm	Samarium
Ce	Cerium	Mn	Manganese	Sn	Tin
Cf	Californium	Mo	Molybdenum	Sr	Strontium
Cl	Chlorine	Mt	Meitnerium	S	Sulfur
Cm	Curium	Na	Sodium	Ta	Tantalum
Co	Cobalt	Nb	Niobium	Tb	Terbium
Cr	Chromium	Nd	Neodymium	Tc	Technetium
Cs	Cesium	Ne	Neon	Te	Tellurium
Cu	Copper	Ni	Nickel	Th	Thorium
Dy	Dysprosium	N	Nitrogen	Ti	Titanium
Er	Erbium	No	Nobelium	Tl	Thallium
Es	Einsteinium	Np	Neptunium	Tm	Thulium
Eu	Europium	Ns	Neilsborium	U	Uranium
Fe	Iron	O	Oxygen	V	Vanadium
F	Fluorine	Os	Osmium	W	Tungsten
Fm	Fermium	Pa	Protactinium	Xe	Xenon
Fr	Francium	Pb	Lead	Yb	Ytterbium
Ga	Gallium	Pd	Palladium	Y	Yttrium
Gd	Gadolinium	Pm	Promethium	Zn	Zinc
Ge	Germanium	Po	Polonium	Zr	Zirconium

Figure A-1 Element Abbreviations and Names

*Note:* From "Los Alamos National Laboratory's Chemistry Division Presents", 2004, *Periodic Table of the Elements: A Resource for Elementary, Middle School, and High School Students*. Retrieved February 11, 2009, from <http://periodic.lanl.gov/default.htm>



### Simplified Periodic Table of the Elements

1 H 1.008																	2 He 4.003						
3 Li 6.941	4 Be 9.012																	5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31																	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.47	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80						
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3						
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 190.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.5	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)						
87 Fr (223)	88 Ra (226)	89 Ac~ (227)	104 Rf (257)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 --- ( )	111 --- ( )	112 --- ( )	114 --- ( )	116 --- ( )	118 --- ( )			118 --- ( )						

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)

#### Template

Atomic Number
Atomic Symbol
Atomic Mass

Figure A-2 Simplified Periodic Table

Note: From "Los Alamos National Laboratory's Chemistry Division Presents", 2004, *Periodic Table of the Elements: A Resource for Elementary, Middle School, and High School Students*. Retrieved February 11, 2009, from <http://periodic.lanl.gov/default.htm>

## Energy

**Scientists**

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**Nationality**

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**Concept**

---

**Experiment**

---

---

---

**Time Period**

---

**Challenges Faced**

---

---

---

**Mass**

**Scientists**

---

**Nationality**

---

---

---

**Concept**

---

**Experiment**

---

---

---

**Time Period**

---

**Challenges Faced**

---

---

---

## Light

**Scientists**

---

**Nationality**

---

---

---

**Concept**

---

**Experiment**

---

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---

**Time Period**

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**Challenges Faced**

---

---

---

## Velocity (Speed of Light Squared)

### Scientists

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### Nationality

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### Concept

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### Experiment

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### Time Period

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### Challenges Faced

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## Development of the Equation $E=mc^2$

**Scientists**

---

**Nationality**

---

---

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**Concept**

---

**Experiment**

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**Time Period**

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**Challenges Faced**

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## Confirmation of the Equation $E=mc^2$

**Scientists**

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**Nationality**

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**Concept**

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**Experiment**

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**Time Period**

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**Challenges Faced**

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## Energy

### Scientist

Michael Faraday.

### Nationality

English.

### Concept

Invisible lines of force flow around electricity and magnets; electricity and magnetism are linked.

### Experiment

Faraday placed a magnet beside a copper wire suspended in mercury and passed an electric current through the wire. The wire spun in a circle around the magnet, thus demonstrating the interaction of lines of electric and magnetic force.

### Time Period

Early 1800s.

### Challenges Faced

Accused of plagiarism by Sir Humphry Davy; refuted claim and was later elected to the Royal Society.



## **Mass**

### **Scientists**

Antoine-Laurent and Marie Anne Lavoisier.

### **Nationality**

French.

### **Concept**

Matter is always conserved in a chemical reaction regardless of how it is transformed.

### **Experiment**

Lavoisier transformed a number of different substances. He carefully measured all the products of the reactions to show that matter is conserved.

### **Time Period**

Late 1700s.

### **Challenges Faced**

The French Revolution; Antoine-Laurent Lavoisier was captured and executed by guillotine.

## Light

### Scientists

Michael Faraday and James Clerk Maxwell.

### Nationality

English (Faraday) and Scottish (Maxwell).

### Concept

Electromagnetism can be described mathematically; Maxwell's equations supported Faraday's long-held claims that light was just one form of electromagnetism.

### Experiment

Maxwell's ideas were theoretical.

### Time Period

Mid-1800s.

### Challenges Faced

Scientists did not agree with Faraday's belief that light was an electromagnetic wave.

## **Velocity (Speed of Light Squared)**

### **Scientists**

Emilie du Châtelet and Gottfried von Leibniz.

### **Nationality**

French (du Châtelet) and German (Leibniz).

### **Concept**

The energy of an object is a function of the square of its speed, rather than its speed.

### **Experiment**

Du Châtelet analyzed experiments in which brass balls were dropped into clay; measuring their impacts demonstrated that an object's energy is a function of its velocity squared. She corrected Newton and clarified Leibniz's original ideas about velocity.

### **Time Period**

Early to mid-1700s.

### **Challenges Faced**

Scientists discounted Leibniz' ideas; du Châtelet died during childbirth when she was 43.

## Development of the Equation $E=mc^2$

### Scientist

Albert Einstein.

### Nationality

German, Swiss, and American.

### Concept

Mass and energy are the same and can be converted from one to the other using the speed of light squared.

### Experiment

Einstein's ideas were theoretical.

### Time Period

Early 1900s.

### Challenges Faced

At first no one responded to Einstein's ideas; he patiently answered letters for four years. His genius began to be recognized when his work gained the endorsement of German physicist Max Planck.

## Confirmation of the Equation $E=mc^2$

### Scientists

Otto Hahn, Fritz Strassmann, Lise Meitner, and Otto Robert Frisch.

### Nationality

German (Hahn, Strassmann) and Austrian (Meitner, Frisch).

### Concept

The confirmation of  $E=mc^2$ .

### Experiment

Hahn and Strassmann bombarded uranium with neutrons and discovered barium in the resulting products; Meitner and Frisch realized the results indicated that Hahn and Strassmann had split the uranium nucleus.

### Time Period

Mid-1900s.

### Challenges Faced

Since she was Jewish, Meitner was forced to flee Germany and compelled to collaborate by mail with Hahn and Strassmann, but Hahn never acknowledged Meitner's work.